Leasing as a Mitigation Channel of Capital Misallocation

Weiwei Hu, Kai Li, and Yiming Xu *

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Abstract

We argue that leasing is an important mechanism for mitigating credit constraint-induced capital misallocation, yet this channel has been widely overlooked in the current macro-finance literature. We demonstrate and quantify this novel channel through a dynamic general equilibrium model, which features heterogeneous firms, collateral constraints, and an explicit buy versus lease decision. Furthermore, our model provides guidance on the empirical measurement of capital misallocation: ignoring leased capital and its mitigation effect can result in significant overestimations of measured capital misallocation and its cyclicality. We use firm-level data to document strong empirical evidence consistent with our model.

JEL Codes: E22, E32, E44

Keywords: Leased capital, Collateral constraint, Capital misallocation, Marginal product of capital, Cyclicality

*Weiwei Hu (weiwei.hu@phbs.pku.edu.cn) is an assistant professor of economics at Peking University HSBC Business School; Kai Li (kaili825@gmail.com) is an associate professor of finance at Peking University HSBC Business School and Sargent Institute of Quantitative Economics and Finance; Yiming Xu (yxuuu06@gmail.com) is a PhD student in economics at Cambridge University. We are grateful for helpful comments from Hengjie Ai, Utpal Bhattacharya, Charles Brendon, Tiago Cavalcanti, Feng Dong (Discussant), David Dicks (Discussant), Andrea Eisfeldt, Chryssi Giannitsarou, Yan Ji, Paymon Khorrami (Discussant), Andrea Lanteri (Discussant), Abhiroop Mukherjee, Gabor Pinter (Discussant), Adriano Rampini, Lukas Schmid (Discussant), Jincheng Tong (Discussant), Pengfei Wang, Toni Whited, Haotian Xiang (Discussant), Jialin Yu, and other seminar and conference participants at SFS Cavalcade North America 2022, Financial Intermediation Research Society (FIRS) Meeting 2022, Royal Economic Society 2022, CICM 2022, CICF 2022, AEA Poster 2022, MFA 2022, FMA 2022, SED 2021, PHBS Macro and Finance workshop 2021, 2021 PKU-NUS Annual Conference, 21st CEA, Cambridge University, CKGSB, Guanghua, and HITSZ. Kai Li gratefully acknowledges the General Research Fund of the Research Grants Council of Hong Kong (Project Number: 16502617) for financial support. The usual disclaimer applies.

1 Introduction

Leasing is extensively used in capital markets and production. We document that leased capital accounts for about 20% of the total productive physical assets used by US publicly listed firms, and this proportion is even higher among small and financially constrained firms - over 40%. However, before the recent lease accounting rule changes in ASC 842, operating lease was treated as an off-balance-sheet item, leaving leased capital as an important source of "unmeasured" capital.[1] Hence, leased capital is largely ignored in the macro-finance literature, especially in economies with financial frictions. In this paper, we argue that leasing is an important mitigation channel of credit constraint-induced capital misallocation. When firms are financially constrained, the possibility for them to lease capital improves capital allocation efficiency and mitigates capital misallocation.[2] We formalize the above idea from both theoretical and empirical perspectives.

We first construct a general equilibrium model with heterogeneous firms, collateral constraints, and an explicit buy versus lease decision. Typically, collateral constraints prevent firms with high financing needs (i.e., the ratio between firm productivity to net worth is high) from acquiring sufficient capital. Hence, these firms face a higher cost of capital (i.e., the multiplier on the collateral constraint is high) and have, ceteris paribus, higher marginal product of capital (MPK). The dispersion in MPK, which is known as capital misallocation, manifests themselves as efficiency losses (Hsieh and Klenow, 2009; Midrigan and Xu, 2014). However, all these models on financial friction-induced misallocation have ignored the

[1]In February 2016, the Financial Accounting Standards Board (FASB) issued updated accounting standards for leases (ASU 2016-02, Topic 842). Effective from 2019, firms are required to recognize lease assets and lease liabilities from off-balance-sheet activities on their balance sheets, thereby increasing the transparency and comparability among organizations. Firms now report "Lease right-of-use asset" on the asset side, and both short-term and long-term lease liabilities on the liability side. These items were absent before the adoption of the new operating lease accounting rule. Additionally, firms are required to report the estimates of their operating leases, including the value, average regaining life, and discount rate, and disclose the possibility of renewing or extending existing leases. Similarly, the International Accounting Standards Board (IASB) also released IFRS 16 on new lease standards, requiring nearly all leases to be reported on lessees' balance sheets as assets and liabilities in 2016, effective for annual periods beginning on or after January 1, 2019. Appendix A.2 provides more detailed institutional backgrounds related to this accounting rule change.

[2]We use "lease" and "rent," "purchase" and "own" interchangeably in this paper.

possibility that firms can rent capital.

We explicitly introduce firms' optimal lease vs. buy decision, modeling leasing as a highly collateralized albeit costly financing tool. In a typical operating lease contract, the owner of the capital (lessor, financier) grants to the borrower (lessee) the exclusive right to use capital for an agreed period in exchange for periodic payments; at the end of the lease's term, the capital reverts to the lessor.[3] The fact that the lessor retains ownership of the asset affords a repossession advantage: according to Chapter 11 of the US bankruptcy code, when the borrower goes bankrupt, it is easier for the lessor to regain its asset than it is for a secured lender to recover the same asset backing the loan.[4] Therefore, leasing effectively extends more credit than a secured lender and is highly collateralized. However, the separation of capital ownership and control rights makes leasing costly, since the lessor must incur a monitoring cost to avoid agency problems. These features are motivated by the practical treatment under US law (and in most legal systems), and they are consistent with Eisfeldt and Rampini (2009) and Rampini and Viswanathan (2013).

As a result, firms with high financing needs find it optimal to lease despite the expensive rents. This alternative capital acquiring method allows these firms to utilize more capital. Their high cost of capital due to the scarcity of net worth (in the case of no leasing) can be effectively alleviated by the user cost of leasing. Hence, these firms' high MPK will be reduced, which leads to a drop in the dispersion of MPK (relative to the case of no leasing). Via such a mitigation effect on capital misallocation, leasing creates a significant efficiency gain to the aggregate economy. Our theory emphasizes such a novel macro-finance perspective, both analytically and quantitatively. To the best of our knowledge, our paper is

[3]The focus of this paper is the off-balance-sheet item operating lease, whose ownership belongs to the lessor. There is another type of lease – capital lease (also known as financial lease), in which the lessee acquires ownership of the asset at the end of the lease's term. Capital lease was already on balance sheets before the lease accounting rule change, and is much lower in magnitude than operating lease in the US - Graham and Lin (2018) document that close to 90% of leased assets are recorded as operating leases.

[4]If the lessee fails to make the specified payments in the middle of the contract, the capital must be returned to the lessor and the contract ends. In contrast, the asset that secures the claim of a secured lender (i.e., the collateral) is subject to automatic stay in Chapter 11 of the US bankruptcy code, which prevents foreclosures on or recoveries of the property.

the first to explicitly model leased capital in a dynamic general equilibrium model with capital misallocation, along with a quantitative efficiency analysis. Our model also speaks of the empirical measurements - it allows us to discuss two measures of MPK and MPK dispersion (lease-adjusted vs. unadjusted) precisely. The model guidance on these measurements brings new features of the level and cyclical patterns of measured capital misallocation, providing an important caveat to the new leases standard from the macro-finance perspective.

Our theoretical analysis is organized into two parts. First, we analyze a simplified two-period version of our model, in which we are able to characterize the equilibrium analytically. Second, we consider a richer quantitative model, which nests our two-period case and has firms' net worth endogenously determined. We use this model to quantify the effect of leasing on capital misallocation and on aggregate efficiency.

In the first part with the two-period model, we come up with several propositions that analytically characterize the equilibrium. Through comparing the user cost of owned capital and leased capital, we show that in the cross-section, firms with higher productivity (relative to net worth) are more likely to become constrained. Moreover, these firms tend to use more leased capital. We then present the aggregation result which demonstrates that the aggregate efficiency negatively depends on capital misallocation. Next, we consider a counterfactual economy in which the rental market is artificially closed. We show that this no-leasing economy generates a larger amount of capital misallocation and a correspondingly lower aggregate efficiency. The comparison between these two economies highlights the role of leasing in mitigating capital misallocation and in improving aggregate efficiency, qualitatively. In addition, our model sheds light on the cyclical pattern of leased capital ratio and capital misallocation in the time series. When firms' initial net worth decreases, the leased capital ratio becomes higher in the economy with leasing, suggesting that leased capital ratio is countercyclical in equilibrium. The countercyclicality of leased capital also has implications for capital misallocation: the dispersion in MPK, interpreted as the benefit of capital reallocation, is not necessarily countercyclical; and it is less countercyclical than that in the no-leasing economy.

In the second part with the quantitative model, we first parameterize the model to match empirical moments observed in the US. We compare the model to the data along various firm-level moments not targeted during the parameterization. We show that our benchmark model generates distributional, within-firm, and cross-sectional patterns that match patterns of key aspects of firm dynamics (i.e., capital, MPK dispersion, and output) in the data. We then proceed to the quantitative analysis of aggregate efficiency. We find that the capital misallocation in our benchmark economy reduces the level of TFP by around 5%, relative to the efficient level. Shutting down the leasing market, capital misallocation nearly doubles, and the TFP losses rise substantially to about 9%. Comparing these two economies, we can conclude that the ability to lease recovers approximately 50% of efficiency losses in the no-leasing economy (4 percentage points of aggregate TFP), by providing an alternative capital allocation channel from the perspective of financially constrained capital borrowers. We conduct a number of exercises in order to gauge the robustness of our benchmark results. We vary the tightness of the collateral constraint and change other key parameters, including the monitoring cost and the process of idiosyncratic transitory shocks. All versions of our model suggest the important role that leasing plays in reducing capital misallocation and in improving aggregate efficiency. Additionally, we provide analyses by considering the transition dynamics associated with changes in the tightness of collateral constraints and monitoring costs. When subjected to these shocks, our model generates dynamics that suggest the cyclical properties of leased capital ratio and MPK dispersion, consistent with our two-period model.

Our model also has strong implications in terms of empirical measurements for capital productivity and capital misallocation. According to our model, it is crucial for us to explicitly account for leased capital in measuring these empirically.[5] However, the current literature

[5]Note that the mechanisms discussed in above three paragraphs are based on the correctly-measured (i.e., true lease-adjusted) MPK and capital misallocation.

(for instance, Chen and Song (2013) and Hsieh and Klenow (2009)) does not consider the fact that firms use not only purchased capital but also leased capital to produce. That is, all existing measures have ignored the component related to leased capital. We use the model guidance to explicitly adjust for lease in measuring MPK and find strong empirical evidence that is consistent with our model predictions.

First, and unconditionally, our model shows that when leased capital is utilized but ignored, there will be an overestimation of MPK dispersion, given the heterogeneity of leasing intensity across different firms. The intuition is simple: ignoring leased capital in the denominator leads to an overestimation of capital productivity, and such overestimation is disproportionately larger for firms that rent more capital. In turn, it tends to exaggerate the capital misallocation measured as capital productivity dispersion. In the data, we employ various methods to capitalize rental expense and obtain a gauge of the amount of leased capital for US publicly listed firms. The methods include Rampini and Viswanathan (2013) and Rampini and Viswanathan (2020).[6] We then find that Hsieh and Klenow (2009) type of capital misallocation can drop by nearly 50% when leased capital is correctly accounted for. This reduction is more salient for small and financially constrained firms.

Second, and conditionally, our model predicts that the lease-adjusted capital misallocation is less countercyclical than the unadjusted misallocation. That is, explicitly accounting for leased capital is also important for us to correct for an overestimation of the cyclical pattern of capital misallocation. We first explore the cyclicality of leased capital ratio in the data. We find that leased capital ratio is highly countercyclical, and this countercyclicality is robust to different aggregation levels, to different measures of leased capital, and to different time-series filtering methods that we use. For example, the cyclical component obtained from the HP-filter has a negative correlation coefficient of -0.50 (t-stat = -3.25) with the cyclical

[6] We also consider other common empirical proxies for the amount of operating leases in our robustness checks, which is equal to the present value of current and future lease commitments, as in Rauh and Sufi (2012), Li, Whited, and Wu (2016), Graham, Lemmon, and Schallheim (1998), Cornaggia, Franzen, and Simin (2013), and Graham and Lin (2018).

component of output. We then examine the cyclical patterns of MPK dispersion. It is well-documented in the literature that the cross-sectional dispersion of MPK is countercyclical (Eisfeldt and Rampini, 2006; Ai, Li, and Yang, 2020). However, the lease-adjusted MPK dispersion becomes less countercyclical for the entire sample of US publicly listed firms. Moreover, if we look further at small firms and financially constrained firms, we find that their capital misallocation becomes acyclical, due to the fact that these firms rent more capital, in particular, in recessions. This evidence is consistent with our model and demonstrates our model prediction that leasing provides an important mitigation effect to capital misallocation. We view these empirical findings as non-trivial contribution to the literature.

Then we provide suggestive causal evidence on the mitigating mechanism of operating leases. We exploit the exogenous variation from the passage of anti-recharacterization laws, which relaxes financial constraints for firms in affected states through increasing secured lenders' ability to repossess assets in bankruptcy (Li, Whited, and Wu, 2016; Chu, 2020). We find that the laws reduce capital misallocation, and such effects are smallest for firms with more accessibility to leasing activities. This empirical finding is consistent with our theory: leasing provides a mitigation to financial friction-induced capital misallocation, since these firms already use leasing as a substitute (for the laws' relaxation effect) in order to improve their capital allocation efficiency ex ante.

Finally, we conduct a number of robustness checks of our empirical results. We first evaluate the sensitivity of our results to the assumption on perfect substitutability between owned capital and leased capital. We find that our results are robust to this assumption. In Appendix G, we directly estimate the elasticity of substitution using the factor share approach (e.g., Chang (1994) and Eisfeldt, Falato, and Xiaolan (2021)) and confirm a high estimate of the elasticity. The sensitivity checks, along with the direct estimation result, as well as the practical treatment of new lease accounting rules (which directly add lease-induced assets to firms' fixed assets), all strongly suggest that our our perfect substitutability assumption is reasonable and innocuous, consistent with the literature (e.g., Eisfeldt and Rampini (2009) and Rampini and Viswanathan (2013)). We also employ alternative measures of leased capital (Rauh and Sufi, 2012; Li, Whited, and Wu, 2016; Graham, Lemmon, and Schallheim, 1998; Cornaggia, Franzen, and Simin, 2013; Graham and Lin, 2018) as well as provide validation tests utilizing the newly-available data after the lease accounting rule change. We confirm the robustness of our results on leased capital ratio and (unadjusted and adjusted) MPK dispersion in all cases.

Related literature Our paper relates to the literature that links aggregate total factor productivity (TFP) to capital misallocation caused by financial frictions at the firm level (for example, Buera, Kaboski, and Shin (2011), Moll (2014), Buera and Moll (2015), and Ai et al. (2019)). Gilchrist, Sim, and Zakrajšek (2013) focus on the cost of debt and study firm-specific borrowing costs. Using plant-level data, Midrigan and Xu (2014) quantify the relationship between financial constraints, capital misallocation, and aggregate TFP in South Korea. Gopinath et al. (2017) explain the decline of TFP and the increase of capital misallocation in South Europe, alongside declining real interest rates. Kehrig and Vincent (2017) study the interaction of financial frictions and adjustment costs in explaining recent dynamics of misallocation within firms. None of these papers, however, focus on the effect of leasing on financial friction-induced capital misallocation as ours does.

Our study builds on the theories of corporate leasing decisions.[7] Miller and Upton (1976), Myers, Dill, and Bautista (1976), Smith Jr and Wakeman (1985), Lewis and Schallheim (1992), and Graham, Lemmon, and Schallheim (1998) all show that taxes create incentives to lease. However, our model focuses on other dimensions, i.e., financial frictions and agency costs associated with the separation of capital ownership and control. The papers most related to ours are Eisfeldt and Rampini (2009), Rampini and Viswanathan (2013), Zhang (2012), Gal and Pinter (2017) and Li and Tsou (2019).[8] We draw elements from these

[7]We provide a more comprehensive review of this literature when discussing the history of leasing in Appendix A.1. See also Eisfeldt and Rampini (2009) for an extensive review.

[8]Chu (2020) uses anti-recharacterization laws as an exogenous shock and provides empirical evidence with respect to the dynamic buy versus lease trade-off argued in the papers described previously. Binfare et al.

papers to construct both collateral constraints and a firm's buy versus lease decision, and the differences lie in two dimensions. First, Eisfeldt and Rampini (2009) is a static model, and Rampini and Viswanathan (2013) and Zhang (2012) are dynamic models with a partial equilibrium framework. Gal and Pinter (2017) adopt a general equilibrium framework to study the aggregate properties, while Li and Tsou (2019) study a general equilibrium model with heterogeneous firms but without misallocation features. For our study, we set up a dynamic general equilibrium model with heterogeneous firms, and this model can generate capital misallocation, whereas none of the above papers feature misallocation or efficiency losses. Second, we focus on the asset side of leased capital, and we discipline our model using dynamics of output, capital, and productivity at the firm level. This allows us to analyze the economic consequences by aggregating micro-level firm behavior.[9]

Our study belongs to the macroeconomics literature with financial frictions. Quadrini (2011) and Brunnermeier, Eisenbach, and Sannikov (2012) provide excellent surveys. Specifically, the papers that are most related to our study include Kiyotaki and Moore (1997), Gertler and Kiyotaki (2010), Kiyotaki and Moore (2012), Brunnermeier and Sannikov (2014), He and Krishnamurthy (2013), and Elenev, Landvoigt, and Van Nieuwerburgh (2018). They all emphasize the importance of borrowing constraints and limited contract enforceability. Gomes, Yamarthy, and Yaron (2015) develop a production-based asset pricing model to discuss the impact of financial frictions on risk premia. Jermann and Quadrini (2012) study the macroeconomic effects of financial shocks. Chen and Song (2013) study how financial frictions can work as a transmission mechanism for news shocks to drive aggregate TFP fluctuations.

(2020) examine firms' choice of discount rates in valuing their leased assets. Kermani and Ma (2020) and Lian and Ma (2021) study asset-based debt and cash flow-based debt. Operating leases are akin to asset-based debt when lessors repossess the leased assets at the end of leasing contracts.

[9]The finance literature that connects firms' capital structure to asset collateralizability is also closely related to our paper. See Albuquerque and Hopenhayn (2004), Schmid (2008), Eisfeldt and Rampini (2007), Rampini and Viswanathan (2010), Rampini and Viswanathan (2013), Nikolov, Schmid, and Steri (2021), and Ai et al. (2020). Unlike most of these studies emphasizing the financing role of collateral, we investigate its implications on the asset side - in particular, the marginal product of capital. Moreover, most of these studies, with the exceptions of Eisfeldt and Rampini (2009) and Rampini and Viswanathan (2013), do not consider the possibility that firms might rent capital, while we explicitly model firms' buy versus lease decision and focus on the macroeconomic implications.

Our study differs from these in that we introduce leasing as a strongly collateralized, albeit costly, form of financing and explore the implications with respect to increasing the aggregate efficiency in the real economy.

More broadly, our paper is connected to the general capital misallocation literature, seminal examples of which include Hsieh and Klenow (2009) and Restuccia and Rogerson (2008) (see Restuccia and Rogerson (2017) and Hopenhayn (2014) for extensive reviews).[10] David and Venkateswaran (2019) develop a methodology to disentangle various sources of capital misallocation. Whited and Zhao (2021) study financial misallocation and find large real losses in China. Dou et al. (2021) discover that misallocation measures provide a more informative stochastic discount factor for capital market valuations. Lanteri and Rampini (2021) study the effect of externalities on capital misallocation and reallocation. Empirically, Hsieh and Klenow (2009), David, Hopenhayn, and Venkateswaran (2016), David and Venkateswaran (2019) and David, Schmid, and Zeke (2020) find substantial capital misallocation in the US. The extant literature neglects leased capital in quantifying capital misallocation, whereas our paper appropriately accounts for the "unmeasured" leased capital to re-estimate capital misallocation for US public firms. Our paper is also related to measurement issues. Bils, Klenow, and Ruane (2021) and David and Venkateswaran (2019) show that about 10% of the observed MPK dispersion in the US is accounted for by additive measurement errors. In contrast, our lease-adjustment accounts for nearly 50% of the observed dispersion. Lease-induced measurement errors are more salient and disproportionately larger for small and financially constrained firms. Hence, our channel is different from that of the additive measurement errors.

Our paper also contributes to the literature that emphasizes the importance of the cyclical properties of capital misallocation. Eisfeldt and Rampini (2006), Kehrig (2015) and Ai, Li,

[10] Apart from the role of financial frictions in capital misallocation mentioned earlier, additional potential sources include adjustment costs (Asker, Collard-Wexler, and De Loecker, 2014), information frictions (David, Hopenhayn, and Venkateswaran, 2016), markups (Peters, 2020; Edmond, Midrigan, and Xu, 2018; Haltiwanger, Kulick, and Syverson, 2018), as well as firm-level risk premia (David, Schmid, and Zeke, 2020), among others.

and Yang (2020) empirically document that the amount of capital reallocation is procyclical while the benefit of capital reallocation (i.e., capital misallocation) is countercyclical. Eisfeldt and Rampini (2006) rationalize these facts using a model in which the cost of capital reallocation is correlated with TFP shocks. Ai, Li, and Yang (2020) study the link between financial intermediation, capital misallocation, and capital reallocation. Lanteri (2018) analyzes a model with endogenous partial irreversibility and used investment goods. Dong, Wang, and Wen (2020) develop a search-based neoclassical model with capacity utilization.[11] Our paper emphasizes the role of leasing as a mitigation of capital misallocation, which allows us to correct for an overestimation of the cyclical pattern of capital misallocation.

The rest of our paper is organized as follows. In Section 2, we develop an equilibrium model with heterogeneous firms, collateral constraint-induced capital misallocation, and buy versus lease decisions. We analyze a simple two-period setting in Section 3 to illustrate the mitigation role of leasing on capital misallocation and to discuss measures of MPK. We present the recursive formulation and equilibrium of our fully dynamic model in Section 4. We then use Section 5 to provide a quantitative efficiency analysis. In Section 6, we test the model implications empirically. We provide robustness checks in Section 7 and conclude this paper in Section 8. The Internet Appendix includes supplementary materials on the history of leasing, data construction, additional empirical results, proofs for propositions, as well as model solutions.

2 Model setup

In this section, we develop a dynamic general equilibrium model with heterogeneous firms, collateral constraints and leased capital. The collateral constraint is standard, as in Kiyotaki and Moore (1997) and Gertler and Kiyotaki (2010). The additional elements are firms' ability

[11] Cui (2017) studies the effects of financing constraints and partial irreversibility on the cyclicality of capital liquidation. See Eisfeldt and Shi (2018) for a survey of the literature on capital reallocation and misallocation.

to lease capital and idiosyncratic productivity shocks. These new elements are critical - they generate capital misallocation and allow us to examine the mitigation effects of leasing.

2.1 Household

The economy is inhabited by a continuum of households, and we index each household with j, which we suppress wherever appropriate. Each household ranks consumption according to log preferences:

$$E_0 \sum_{t=0}^{\infty} \beta^t \log\left(C_t^H\right), \tag{1}$$

where β is the time discount factor and C_t^H is consumption at time t.

The household maximization problem is subject to the following intertemporal budget constraint:

$$C_t^H + B_{t+1} + K_{t+1}^l = W_t \nu_t + R_{ft} B_t + \tau_{lt} K_t^l + (1 - \delta - h) K_t^l. \tag{2}$$

At time t, the household consumes C_t^H and preserves B_{t+1} amount of cash for purchasing risk-free bonds. The household also serves as the lessor: it can transform net worth into K_{t+1}^l amount of leased capital and rent to firms. The income of the household consists of the following: first, the household gets the leasing payment $\tau_{lt} K_t^l$ for the capital rented out to firms, where τ_{lt} is the leasing fee per unit of leased capital. Second, the household gets the resale value of leased capital $(1 - \delta - h) K_t^l$ returned by firms after production. δ is the rate of capital depreciation, and h is the monitoring cost of leased capital due to the separation of ownership and control, as in Eisfeldt and Rampini (2009) and Rampini and Viswanathan (2013).[12] Eventually, the household receives the debt repayment $R_{ft} B_t$ and the labor income $W_t \nu_t$, where R_{ft} is the gross risk-free interest rate, and ν_t is the labor efficiency.

In this setup, the first-order condition of K_t^l implies that $R_{ft} = \tau_{lt} + 1 - \delta - h$. That is, the household faces a no-arbitrage condition between the returns on supplying risk-free

[12] h captures the disadvantages of leased capital related to its faster depreciation rate in production and more costly maintenance. Note that firms will return the leased capital to the household after production.

bonds and on supplying leased capital. We can further write it as $\tau_{lt} = R_{ft} - 1 + \delta + h$. This equation shows the cost per unit of leased capital, in the notion of Jorgenson (1963). We can see that the only difference between τ_{lt} and the rental cost in the frictionless neoclassical model is the positive monitoring cost h.

2.2 Nonfinancial firms

There are two types of nonfinancial firms in our model: final goods producers and intermediate goods producers.[13]

2.2.1 Final goods producers

Final goods are produced by a representative firm using a continuum of intermediate inputs indexed by $i \in [0, 1]$. We normalize the price of final goods to one and write the profit maximization problem of a final goods producer as:

$$\max_{y_{it}} \left\{ Y_t - \int_{[0,1]} p_{it} y_{it} di \right\}_{Y_t = \left[\int_{[0,1]} y_{it}^{\frac{\eta-1}{\eta}} di \right]^{\frac{\eta}{\eta-1}}}, \tag{3}$$

where p_{it} and y_{it} are the price and quantity of input i at t, respectively, and Y_t stands for the total output of final goods. The parameter η is the elasticity of substitution across input varieties. The optimality condition implies that the demand of the final goods producer is $y_{it} = p_{it}{}^{-\eta} Y_t$.

2.2.2 Intermediate goods producers

There is a unit measure of intermediate goods producers, $i \in [0, 1]$, each of which produces a different variety of goods and competes monopolistically.

[13] We use "firm" and "intermediate goods producer" interchangeably in the remainder of the paper.

Each firm faces a Cobb-Douglas production technology:

$$y_{it} = z_i^P z_{it}^T \left(K_{it}^o + K_{it}^l\right)^\alpha L_{it}^{1-\alpha}, \tag{4}$$

where $\alpha < 1$ is the capital share in production, and y_{it} is the output produced using owned capital K_{it}^o, leased capital K_{it}^l, and labor L_{it}. z_i^P is an idiosyncratic permanent productivity component, and z_{it}^T is an idiosyncratic transitory productivity that evolves over time. Owned capital and leased capital are assumed to be perfect substitutes in production, following previous studies (e.g., Eisfeldt and Rampini (2009), Rampini and Viswanathan (2013), and Rampini (2019)).[14]

Firm i's budget constraint can then be summarized as:

$$C_{it} + K_{i,t+1}^o - (1-\delta)K_{it}^o = p_{it}y_{it} - \tau_{lt}K_{it}^l - R_{ft}B_{it} - W_tL_{it} + B_{i,t+1}. \tag{5}$$

The right-hand side of this constraint states that at each time t, firm i produces output y_{it} and sells at p_{it}, pays back wage W_tL_{it}, bond and interest $R_{ft}B_{it}$, as well as the leasing fees $\tau_{lt}K_{it}^l$. With the borrowing $B_{i,t+1}$ from the household, firm i determines its consumption C_{it} and the new capital amount to be purchased $K_{i,t+1}^o - (1-\delta)K_{it}^o$, as the left-hand side suggests. For the depreciated leased capital, firms will return it to the household after production.

The amount of the borrowing $B_{i,t+1}$ is subject to a collateral constraint:

$$B_{i,t+1} \leq \theta K_{i,t+1}^o, \tag{6}$$

in which θ is the collateralizability characterizing the collateral constraint. It means that a maximum of θ fraction of the owned capital can be retrieved upon default.

[14] This assumption is also reasonable and innocuous for the following reasons. First, after the accounting rule changes in 2019, firms must report operating leases as "Lease right-of-use asset", and firms' fixed assets (PPENT, as in Compustat database) now include "Lease right-of-use asset" by assuming that leased capital and owned capital are perfect substitutes (Section 7.3.1 and Appendix A.2). Second, in Appendix G, we directly estimate the degree of elasticity between these two types of capital in the data, and find a very high estimate, which is in favor of the perfect substitute assumption. Lastly, in our empirical results, we alter the substitutability to allow for imperfect substitutability between owned and leased capital, and confirm the robustness (Section 7.1).

Firm i maximizes its life-time utility given by: $E_0 \sum_{t=0}^{\infty} \beta^t \log(C_{it})$, by choosing owned capital $K^o_{i,t+1}$, leased capital K^l_{it}, borrowing $B_{i,t+1}$, labor L_{it}, price p_{it} for its output[15], and consumption C_{it}, subject to the budget constraint (5) and the collateral constraint (6). Our specification of a firm maximizing utility (based on its consumption) is similar to Buera and Moll (2015) and Moll (2014).

The firm problem is where our model departs from the frictionless neoclassical setup. The key constraint for borrowing is $B_{i,t+1} \leq \theta K^o_{i,t+1}$. Without this collateral constraint, our model reduces to the frictionless neoclassical model.

2.3 Market clearing condition

In this part, we list the market clearing to complete the specification of the model.

$$\int C^H_{jt} dj + \int C_{it} di + \int K^o_{i,t+1} di - (1-\delta) \int K^o_{it} di + \int K^l_{j,t+1} dj - (1-\delta-h) \int K^l_{jt} dj = Y_t, \quad (7)$$

$$\int B_{jt} dj = \int B_{it} di, \quad (8)$$

$$\int K^l_{jt} dj = \int K^l_{it} di, \quad (9)$$

$$\int L_{it} di = 1. \quad (10)$$

The first equation is the market clearing conditions for final output at time t. Eq. (8) corresponds to the bond market clearing condition. Eq. (9) is the leased capital market clearing condition. The last equation represents the labor market clearing condition, for which we have normalized the total efficient labor supply to one.

[15] The price is a choice variable here since our fully dynamic setup features monopolistic competition.

3 The two-period case

To demonstrate the key economic mechanism, in this section, we analyze a two-period version of our dynamic model and understand how a firm's net worth affects macro quantities. In the fully dynamic model discussed in Sections 4 and 5, a firm's net worth will be endogenously determined, but the basic mechanism remains the same.

We first make several simplifying assumptions. Then we discuss the collateral binding conditions, buy versus lease decisions, and the aggregation result. We next study the (mis)measurement in MPK and in MPK dispersion. Finally, we qualitatively show the mitigating role of leasing by analyzing a counterfactual economy in which the leasing market is shut down.

3.1 Simplifying assumptions

For simplicity's sake, we first assume that the household has initial wealth Ω_0 and provides one unit of efficient labor. Second, we assume that firms have risk neutral utility and are endowed with the same initial net worth N_0. Third, we simplify the monopolistic competition feature in the full setup to perfect competition, which we will resume in Sections 4 and 5.[16] Fourth, we assume that the idiosyncratic permanent productivity is always one and that the idiosyncratic transitory productivity z_{i1}^T at period 1 has two possible realizations (z_L and z_H), with $Prob(z_{i1}^T = z_H) = 1 - Prob(z_{i1}^T = z_L) = \pi$.

The last assumption we make is on the timing. We assume that firm i observes its idiosyncratic productivity in advance and then decides the amount for the owned capital and leased capital. This assumption of "observing idiosyncratic shock ahead of time" is standard in the investment literature, as in Moll (2014) and Midrigan and Xu (2014). It is also consistent with the view that managers enjoy information advantages because of their

[16] We also discuss a two-period case with monopolistic competition and/or with additional costs of using leased capital. Our main intuitions remain the same. See Appendix D for more details.

potential insider information.

To facilitate discussion, we fit in a set of plausible parameters and compute a numerical example. The notes of Figure 1 report all the parameter values used in the example. We describe the details of our two-period model in Appendix C.1.

3.2 Collateral constraint and buy versus lease decision

We use this section to discuss whether a firm becomes constrained and whether it leases capital.

3.2.1 Collateral constraint

Given that firms are endowed with the same N_0 but have two types of productivities, they naturally become constrained differently. The following proposition characterizes the nature of the binding constraints.

Proposition 1. *There exist cutoff values $\widehat{N}$ and $\overline{N}$, such that*

- *If $N_0 \geq \widehat{N}$, then the first best allocation is achieved.*
- *If $\overline{N} \leq N_0 < \widehat{N}$, then the collateral constraints for high productivity firms bind.*
- *If $0 < N_0 < \overline{N}$, then the collateral constraints for both types of firms bind.*

Proof. See Appendix C.3.1

The above proposition implies that given the initial net worth N_0, whether a firm is constrained is completely determined. When initial net worth N_0 is higher than $\widehat{N}$, the wealth level is high enough so the collateral constraints never bind. As the net worth level decreases, when $\overline{N} \leq N_0 < \widehat{N}$, the collateral constraint binds only if the firm receives a high productivity shock, because this firm has higher financing needs and requires more capital to arrive at the first best allocation. In the region where $0 < N_0 < \overline{N}$, firms are endowed with little net worth and the collateral constraints bind for both realizations of idiosyncratic transitory productivity shocks.

Proposition 1 has several important implications. First, in the cross-section, the collateral constraint is more likely to bind for firms with high idiosyncratic productivity. Second, in the time series, the collateral constraint is more likely to bind when firms' initial net worth is low. This is the amplification mechanism in our model. Adverse shocks to firms' initial net worth are amplified because they tighten the collateral constraints.

3.2.2 Buy versus lease decision

Leasing has its benefits and costs. In the following, we present the user costs to analyze firms' decision on whether to lease or to buy capital.

We set up the Lagrangian of a typical firm i. We denote the multipliers on Eqs. (C6), (C7), (C8) and the non-negativity of K_{i1}^o, K_{i1}^l and C_{i1} by η_{i0}, η_{i1}, $\xi_{i0}\eta_{i0}$, $\bar{\nu}_{i0}\eta_{i0}$, $\underline{\nu}_{i0}\eta_{i0}$, and d_{i1}, respectively.[17] In terms of consumption at period 0, the user cost of leased capital is:

$$\tilde{\tau}_{l,i} = M_1 \frac{\tau_l}{\eta_{i0}} = \frac{M_1}{\eta_{i0}} \tau_l = \tilde{M}_i (R_f - 1 + \delta + h), \tag{11}$$

that is, the leasing fee in terms of the marginal value of net worth for firm i, $\frac{\tau_l}{\eta_{i0}}$, discounted by $M_1 = \frac{1}{R_f}$. η_{i0} is the marginal value of net worth for firm i at time 0.

We define firm i's user cost of buying owned capital as:

$$\tilde{\tau}_{o,i} = 1 - \tilde{M}_i (1 - \delta) - \theta \xi_{i0}. \tag{12}$$

The interpretation is that the user cost of buying owned capital is equal to the current price, 1, minus the discounted resale value, and also subtract the marginal value of relaxing the collateral constraint for owning this capital.

We define a wedge Δ_i, which is determined by $\Delta_i = \frac{1}{\tilde{M}_i} - R_f = R_f \left(\eta_{i0} - 1\right) = R_f \frac{\xi_{i0}}{1 - \xi_{i0}} \equiv$

[17] We outline these details in Appendix C.2.

$\Delta(\xi_{i0})$. Δ_i is an increasing function of ξ_{i0}. When the collateral constraint is binding, this wedge becomes strictly positive.[18] Using this wedge and the net interest rate $r_f = R_f - 1$, we can re-write the two user costs as:

$$\tilde{\tau}_{l,i} = \tilde{M}_i \tau_l = \frac{r_f + \delta + h}{R_f + \Delta_i}, \tag{13}$$

and

$$\tilde{\tau}_{o,i} = \frac{r_f + \delta + \Delta_i}{R_f + \Delta_i} - \theta \xi_{i0}. \tag{14}$$

The difference between the two user costs (lease - own) is thus:

$$\tilde{\tau}_{l,i} - \tilde{\tau}_{o,i} = \frac{h}{R_f + \Delta_i} - \frac{\Delta_i}{R_f + \Delta_i} + \theta \xi_{i0} = \frac{\eta_{i1}}{\eta_{i0}} h + \xi_{i0}(\theta - 1). \tag{15}$$

The benefit of leasing is the premium saved on internal funds due to constraints, while the cost of leasing includes the additional monitoring cost and the cost of giving up the marginal value of relaxing the collateral constraint when buying this capital. In the environment of collateral constraint, ξ_{i0} is non-negative and $\theta < 1$. When firms become sufficiently constrained (ξ_{i0} sufficiently large), the benefit of leasing dominates its cost, and firms start to lease.

Firms that are differently constrained will naturally make different leasing decisions. The following proposition characterizes the properties of leasing decisions.

Proposition 2. *There exist cutoff values $\widehat{N}_L$ and $\overline{N}_L$, such that*

- *If $N_0 \geq \widehat{N}_L$, then no firms lease capital.*
- *If $\overline{N}_L \leq N_0 < \widehat{N}_L$, then only high productivity firms lease capital.*
- *If $0 < N_0 < \overline{N}_L$, then both types of firms lease capital.*
- *Under reasonable parameter values for the monitoring cost, h, $\overline{N}_L < \overline{N} < \widehat{N}_L < \widehat{N}$.*

[18] To gain intuitions, we denote and interpret $\frac{1}{\tilde{M}_i}$ as a shadow interest rate for the borrowing and lending among firms $R_{I,i}$. Hence, a positive wedge Δ_i reflects a premium that firms must pay for the loans among themselves, when cheaper household loans become inaccessible due to a binding collateral constraint.

Proof. See Appendix C.3.2

Proposition 2 implies that given the initial net worth N_0, firms' buy versus lease decisions are completely determined. When initial net worth N_0 is higher than $\widehat{N}_L$, the wealth level is high enough and no firms will use the costly leased capital. As the net worth level decreases, when $\overline{N}_L \leq N_0 < \widehat{N}_L$, only those firms that receive a high idiosyncratic productivity shock choose to lease. In the region in which $0 < N_0 < \overline{N}_L$, both types of firms lease. Compared with Proposition 1, we have $\overline{N}_L < \overline{N} < \widehat{N}_L < \widehat{N}$ under reasonable parameters. That is, firms lease capital only if they become sufficiently constrained. High productivity firms lease before low productivity firms become constrained. Meanwhile, leased capital is more likely to be used when firms' initial net worth is low, indicating that leasing is countercyclical.

3.2.3 Graphic illustration

In Figure 1, we plot the collateral constraint multipliers on the left and leased capital ratio on the right. We denote the thresholds $\widehat{N}$, $\overline{N}$, $\widehat{N}_L$, and $\overline{N}_L$ as in our propositions. Indeed, we find that increases in firms' initial net worth above $\widehat{N}$ do not affect the collateral multipliers, because productivity is constant and capital allocation stays at its first-best level. As N_0 decreases toward $\overline{N}$, the collateral constraint only binds for high productivity firms. When high productivity firms become sufficiently constrained ($N_0 < \widehat{N}_L$), they begin to lease. As N_0 drops below $\overline{N}$, the collateral constraint for both firms binds. Based on our parameter choice, $\overline{N} < \widehat{N}_L$. Thus, high productivity firms lease capital before low productivity firms become financially constrained. Similarly, when low productivity firms become constrained above a certain level ($N_0 < \overline{N}_L$), they start to lease capital.

[Place Figure 1 about here]

The fact that leased capital ratio increases when N_0 decreases sheds light on its cyclical pattern. Since N_0 is positively related to the aggregate shock, the leased capital ratio is countercyclical.

3.3 Aggregation of the product market

We denote K_H as the total amount of capital used by a high productivity firm at period 1, K_L as the total capital used by a low productivity firm at period 1, and $K = \pi K_H + (1-\pi) K_L$ as the total capital in the economy. Note that K_H, K_L and K include both the owned capital and leased capital. We define a capital ratio between a high productivity and a low productivity firm as $\phi = \frac{K_H}{K_L}$. We can write aggregate output as a function of ϕ, which is specified in the following proposition.

Proposition 3. *The total output of the economy at period 1 is $Y = f(\phi) K^\alpha L^{1-\alpha}$, where the function $f : \left[1, \hat{\phi}\right] \to [0,1]$ is defined as:*

$$f(\phi) = \left\{ (1-\pi) z_L^{\frac{(\eta-1)}{\alpha\eta-\alpha+1}} \left(\frac{1}{1-\pi+\pi\phi} \right)^{\frac{\alpha(\eta-1)}{\alpha\eta-\alpha+1}} + \pi z_H^{\frac{(\eta-1)}{\alpha\eta-\alpha+1}} \left(\frac{\phi}{1-\pi+\pi\phi} \right)^{\frac{\alpha(\eta-1)}{\alpha\eta-\alpha+1}} \right\}^{\frac{\alpha\eta-\alpha+1}{(\eta-1)}},$$

and $\hat{\phi} = \left(\frac{z_H}{z_L}\right)^{\eta-1}$.

We assume the following normalization: $(1-\pi) z_L^{\eta-1} + \pi z_H^{\eta-1} = 1$.

The (true) marginal product of low and high productivity firms, MPK_L and MPK_H,[19] *can be written as:*

$$MPK_L = \alpha f(\phi) K^{\alpha-1} [(1-\pi) + \pi\phi] \left\{ (1-\pi) + \pi \hat{\phi}^{\frac{1}{\alpha\eta-\alpha+1}} \phi^{\frac{\alpha(\eta-1)}{\alpha\eta-\alpha+1}} \right\}^{-1},$$

$$MPK_H = \hat{\phi}^{\frac{1}{1+\alpha\eta-\alpha}} \phi^{\frac{-1}{1+\alpha\eta-\alpha}} MPK_L.$$

Proof. See Appendix C.3.3

It is not hard to show that the efficient level of ϕ is $\hat{\phi} = \left(\frac{z_H}{z_L}\right)^{\eta-1}$ and $f(\hat{\phi}) = 1$, which implies an equalization of MPK across all firms. The function $f(\phi)$ is a measure of the efficiency in the entire economy and is increasing in ϕ.

[19] These MPK expressions correspond to the true adjusted $MPK^{adj.}$s, which we discuss in Section 3.4.

3.4 MPK, capital misallocation, and the measurements

In this section, we discuss the measurement of marginal productivity, which is a key aspect of production. We first describe two types of MPK: the adjusted MPK and the unadjusted MPK. We then analyze two corresponding types of measured capital misallocation: the adjusted as well as the unadjusted misallocation, using the cross-sectional dispersion of $\log(MPK)$.

3.4.1 MPK

In the data, the first-order derivative (MPK) is not directly available. Thanks to the above production function assumption, we have the **true** adjusted MPK as:

$$MPK^{adj.} = \alpha \frac{p_i y_i}{K^o_{i1} + K^l_{i1}} = \alpha \frac{\textit{Value-Added}}{\textit{Total Capital}}.$$

If we ignore the existence of leased capital, we will have the unadjusted MPK as:

$$MPK^{unadj.} = \alpha \frac{p_i y_i}{K^o_{i1}} = \alpha \frac{\textit{Value-Added}}{\textit{Owned Capital}}.$$

We observe that, these two forms of MPK are only different when leased capital is used in production at the corresponding productivity. Using $MPK^{unadj.}$ leads to an overestimation of the true MPK level in this case. The overestimation is more severe for firms with substantial amounts of leased capital. We note that the $MPK^{adj.}$s are the MPKs mentioned in Proposition 3.

Propositions 1 and 2 together show that each firm's adjusted and unadjusted MPKs are completely determined. Given the same wealth, firms with high idiosyncratic productivities are more likely to lease capital. Their adjusted MPKs are thus more likely to be overstated.

3.4.2 Capital misallocation

We now discuss capital misallocation (i.e., MPK dispersion), which we calculate using the cross-sectional variance of MPK (in log). Capital misallocation (and its measurement) is important, as it is closely related to the aggregate efficiency of the economy, as pointed out in Proposition 3. There are two types of misallocation, which we discuss one by one.

Adjusted misallocation Because we assume two types of idiosyncratic productivity, the cross-sectional variance of $\log(MPK^{adj.})$ can be computed as:

$$\begin{aligned} Var[\log\left(MPK^{adj.}\right)] &= E\left[\left\{\log\left(MPK^{adj.}\right) - E\log(MPK^{adj.})\right\}^2\right] \\ &= \pi(1-\pi)\left[\log\left(MPK_H^{adj.}\right) - \log(MPK_L^{adj.})\right]^2. \end{aligned} \tag{16}$$

This equation suggests that given the probability π, the dispersion of $\log(MPK^{adj.})$ is measured by the distance between $\log(MPK_H^{adj.})$ and $\log(MPK_L^{adj.})$, or the ratio of $\frac{MPK_H^{adj.}}{MPK_L^{adj.}}$.

From Proposition 3, we know $\frac{MPK_H^{adj.}}{MPK_L^{adj.}} = \hat{\phi}^{\frac{1}{1+\alpha\eta-\alpha}}\phi^{\frac{-1}{1+\alpha\eta-\alpha}}$, which is decreasing in ϕ and hence in the efficiency measure $f(\phi)$. That is to say, we can directly infer efficiency losses using the adjusted capital misallocation: the larger adjusted misallocation, the lower aggregate efficiency $f(\phi)$ (and equivalently, the larger efficiency losses).

When all firms are unconstrained, they optimally choose their capital and hence $\phi = \widehat{\phi}$. There is no capital misallocation. When some firms become constrained (but not to the point where all firms lease), firms cannot choose the optimal allocation, misallocation occurs and $\phi < \widehat{\phi}$.

Specifically, in the region in which high productivity firms become constrained but low productivity firms are unconstrained, high productivity firms cannot choose the optimal allocation, in this case $\phi < \widehat{\phi}$, and misallocation is non-zero. When high productivity firms become more constrained while low productivity firms are still unconstrained, ϕ goes down and misallocation rises. If high productivity firms begin to lease capital while low productivity firms can still achieve the optimal allocation, we see a constant wedge h between two MPKs by comparing Eqs. (C18) and (C19). ϕ achieves a relatively low value, and hence the misallocation still exists. When high productivity firms lease and low productivity firms become constrained, the MPK difference h is offset by the higher user cost of owned capital for low productivity firms. As a result, ϕ goes up and misallocation decreases.[20]

Undjusted misallocation The cross-sectional variance of $\log(MPK^{unadj.})$ is calculated as:

$$\begin{aligned} Var[\log\left(MPK^{unadj.}\right)] &= E\left[\left\{\log\left(MPK^{unadj.}\right) - E\log(MPK^{unadj.})\right\}^2\right] \\ &= \pi(1-\pi)\left[\log\left(MPK_H^{unadj.}\right) - \log(MPK_L^{unadj.})\right]^2. \end{aligned} \tag{17}$$

This expression indicates that given the probability π, the dispersion of $\log(MPK^{unadj.})$ is measured by the distance between $\log(MPK_H^{unadj.})$ and $\log(MPK_L^{unadj.})$, or the ratio of $\frac{MPK_H^{unadj.}}{MPK_L^{unadj.}}$.

Denote $s_i = \frac{K_{i1}^l}{K_i}$, where $K_i = K_{i1}^o + K_{i1}^l$ and $i = H, L$, we have:

$$\frac{MPK_H^{unadj.}}{MPK_L^{unadj.}} = \frac{MPK_H^{adj.}}{MPK_L^{adj.}} \times \frac{1-s_L}{1-s_H} = \hat{\phi}^{\frac{1}{1+\alpha\eta-\alpha}} \phi^{\frac{-1}{1+\alpha\eta-\alpha}} \frac{1-s_L}{1-s_H}. \tag{18}$$

Eq. (18) suggests that it is now unreliable to only use unadjusted MPK dispersion to infer the aggregate efficiency $f(\phi)$ (or true efficiency losses) - we must adjust for the leased capital ratio s_i.

In cases in which no firms lease capital, the unadjusted MPK dispersion is the same as the adjusted MPK dispersion: there is no capital misallocation when all firms are unconstrained since they can optimally choose their capital; and misallocation occurs when some firms

[20]Eventually, when both types begin to lease, $\widehat{\phi} = \phi$ and no misallocation occurs in the economy since all firms have the adjusted MPK equal to $r_f + \delta + h$, as indicated by Eq. (C19) with $\underline{\nu}_{i0}$ equal to 0. Under the setup with fixed cost in Appendix C.4 and Appendix D.2, we show when both firms lease, misallocation still exists. Nevertheless, all our results indicate that misallocation doesn't necessarily go up when initial net worth drops.

become constrained.

From Proposition 2, we know that firms with the same initial wealth but high productivity are more likely to lease capital. When high productivity firms use leased capital (but low productivity firms don't yet lease), the unadjusted MPK dispersion overstates the adjusted MPK dispersion because of the additional term of $(1 - s_H)$ in the denominator. When both types of firms use leased capital, the unadjusted misallocation achieves the highest level, unlike the adjusted misallocation being zero. This is because when all firms lease, they have the same adjusted MPK, implying that ϕ is constant. The term $\frac{1-s_L}{1-s_H}$ is also constant because firms will buy the same amount of owned capital (up to the constraint).

3.4.3 Graphic illustration

We denote the thresholds $\widehat{N}$, $\overline{N}$, $\widehat{N}_L$, and $\overline{N}_L$ as in our propositions. Then we plot MPKs under our parameter choices.

[Place Figure 2 about here]

In the left panel of Figure 2, we plot the adjusted MPKs for both firm types. For initial wealth above $\widehat{N}$, there is no capital misallocation because both firms are unconstrained. When N_0 decreases to the level lower than $\widehat{N}$, high productivity firms become constrained and their MPK increases because of an additional element on the collateral multiplier. This is the capital misallocation induced by financial frictions, as argued in a large body of literature. As long as $N_0 > \widehat{N}_L$, no firms lease capital and the increase of misallocation is associated with the drop in N_0. Meanwhile, the adjusted MPK is the same as the unadjusted MPK since no leased capital is utilized in the economy yet.

As soon as $N_0 < \widehat{N}_L$, high productivity firms begin to lease in order to relax the collateral constraints. That is, leased capital adds an upper bar to the adjusted MPK for high productivity firms (but the adjusted MPK does change since R_f is endogenous and changes with the initial net worth N_0). Within this region, high productivity firms have an adjusted

MPK of $r_f + \delta + h$. The adjusted MPK for low productivity firms is $r_f + \delta$. We can easily see there is a constant wedge h. When N_0 further drops below $\overline{N}$, the divergence between two adjusted MPKs is lower since low productivity firms become more constrained and have a higher MPK. Eventually, both firms lease capital ($N_0 < \overline{N}_L$) and the MPK divergence disappears in the economy. In summary, the adjusted MPK dispersion does not necessarily increase when net worth decreases, which suggests that the adjusted MPK dispersion is less countercyclical, or even acyclical.

We plot the unadjusted MPKs on the right panel in Figure 2. We notice that only when initial wealth is below $\widehat{N}_L$ will the unadjusted MPKs start to deviate with the adjusted ones. Indeed, it shows that dispersion of the unadjusted MPK overstates the adjusted MPK dispersion when leased capital is in use ($K_{i1}^l > 0$).

Further decreases in initial wealth bring greater dispersion between the unadjusted MPKs. This implies that Hsieh and Klenow (2009) type of misallocation rises as firms' net worth declines. Our model features countercyclical unadjusted MPK dispersion, consistent with the empirical evidence in Eisfeldt and Rampini (2006) and Ai, Li, and Yang (2020).

3.5 The mitigation effect of leasing

We now analyze a counterfactual case, in which the rental market is shut down. In this no-leasing economy, both types of firms become financially constrained eventually. According to the budget constraint (C6) and collateral constraint (C8), they can only have capital up to the level of $\frac{1}{1-\theta}N_0$. In this case, ϕ is as low as 1 and misallocation is large. However, in the economy with leasing, both firms can turn to leased capital and achieve a higher ϕ with lower misallocation. This is the mitigation effect of leasing on capital misallocation. We discuss the details below. Note that in this no-leasing economy, the adjusted and unadjusted MPKs are the same since no leased capital is allowed.

Counterfactual analysis: MPK dispersion In the bottom panel of Figure 3(a), when N_0 decreases to a level lower than $\widehat{N}$, the MPKs for two types of firms diverge since only the high productivity firms become constrained. With a further drop in initial net worth N_0, the constraints for low productivity firms will also bind. The MPK dispersion still exists and further increases since firms are constrained differently. This is the mechanism that generates countercyclical dispersion of MPKs in most macroeconomic models without a rental market.

[Place Figure 3 about here]

It is noteworthy that the point in which both firms become constrained (i.e., $\tilde{N}$) in this economy is different from that threshold in the model with a rental market ($\overline{N}$). Because leasing endogenously improves the capital allocation and lifts R_f, shutting it down will lead to a low interest rate; hence, a higher initial net worth is needed for low productivity firms to be unconstrained.

To gain intuitions for higher misallocation without a rental market, we look at the region between $\tilde{N}$ and $\widehat{N}_L$. When the rental market shuts down, naturally the adjusted MPK for high productivity firm is higher than its counterpart in the benchmark model since there is no additional leased capital to utilize. The adjusted MPK for a low productivity firm without the rental market is lower than its counterpart because of a lower interest rate. A higher-than-before adjusted MPK for high productivity firms, along with a lower-than-before adjusted MPK for low productivity firms, implies higher misallocation when the rental market is closed.

Counterfactual analysis: aggregate outcome We demonstrate the impact of leasing on aggregate efficiency in Figure 3(b). We can clearly see the difference between economies with and without the rental market: when initial net worth is relatively low, the aggregate efficiency measure is higher in the benchmark economy than that in the economy without the rental market.[21] In other words, Figure 3(b) strongly suggests that the impact of leasing on the whole economy is more pronounced in the crisis region.

4 The dynamic model

Having illustrated the main mechanism, we now revert to our fully dynamic model. We resume the monopolistic competition feature and add back the idiosyncratic permanent productivity component z_i^P. We define $N_{A,it} = K_{it}^o - B_{it}$ as firm i's net worth at time t. Unlike our two-period case, this net worth is now endogenously determined. We first present the recursive formulation and equilibrium. We then extend Proposition 3 to represent aggregate efficiency as a function of variables that summarize capital misallocation.

4.1 Recursive formulation and equilibrium

In our dynamic setting, we still adopt the assumption that capital and borrowing decisions are made after observing next period's idiosyncratic productivity (Moll, 2014; Buera and Moll, 2015; Midrigan and Xu, 2014). This assumption allows us to reformulate our problem into a two-step procedure, with the first step suggesting that firm profit is a function of its net worth only.[22]

Using primes to denote next-period variables and dropping firm index i, we can rewrite the firm's problem in recursive form. Specifically, under prices W, R_f, and τ_l, the Bellman equation of a firm with net worth N_A, idiosyncratic transitory productivity z^T, and idiosyncratic permanent productivity z^P under prices W, R_f, and τ_l, is given by:

$$V\left(N_A, z^P, z^T\right) = \max_{N_A', C} \log C + \beta E\left[V\left(N_A', z^P, z^{T\prime}\right)\right]. \tag{19}$$

[21] It seems puzzling that leasing will give us the first-best outcome. We argue that leasing generates a constrained efficient outcome since firms are already endowed with low and insufficient initial net worth.

[22] This assumption conveniently simplifies our analysis by reducing the dimensionality of the state-space and allows us to focus solely on the role of financial frictions in distorting the allocation of capital among firms.

subject to the budget constraint:

$$C + N'_A = \pi(N_A, z^P, z^T) + R_f N_A, \tag{20}$$

and the borrowing constraint:

$$K^o \leq \frac{1}{1-\theta} N_A, \tag{21}$$

where

$$\pi(N_A, z^P, z^T) = \max_{p,\, K^o,\, K^l,\, L} p z^P z^T \left(K^o + K^l\right)^\alpha L^{1-\alpha} - (R_f - 1 + \delta)K^o - \tau_l K^l - WL. \tag{22}$$

We are now in a position to define the equilibrium of our fully dynamic economy. A stationary equilibrium is a set of prices W, R_f, and τ_l, policy functions for households' consumption $C^H(N_A, \nu)$, saving through bonds $B(N_A, \nu)$, and accumulated leased capital $K^l(N_A, \nu)$, for firms' consumption $C(N_A, z^P, z^T)$ and net worth $N'_A(N_A, z^P, z^T)$, as well as output, labor, owned capital, leased capital, and price decisions by firms, $y(N_A, z^P, z^T)$, $L(N_A, z^P, z^T)$, $K^o(N_A, z^P, z^T)$, $K^l(N_A, z^P, z^T)$, $p(N_A, z^P, z^T)$ that: (i) solve the firms' and households' optimization problems; and (ii) satisfy the market clearing conditions for the bond market, the leased capital market, and the labor market, respectively.[23]

4.2 Aggregation of the product market

We now discuss the aggregation results in our dynamic model. Let K_i denote the total amount of capital used by firm i, i.e., $K_i = K_i^o + K_i^l$. For the aggregate quantities in the economy, we use K^o to denote the total amount of owned capital, K^l to denote the total amount of leased capital, K to denote the total amount of utilized capital, and L to denote the total amount of labor. We integrate the decision rules for labor and capital across firms,

[23] For the household, N_A denotes its asset holdings, i.e., bond holdings, which is effectively B. We unify "net worth" of household and firm here.

and obtain the following expression for the total amount of output produced:

$$Y = \text{TFP x } K^{\alpha} L^{1-\alpha}, \tag{23}$$

where TFP is:

$$\text{TFP} := \frac{\left[\int \left(z_i^P z_i^T\right)^{\eta-1} (MPK_i)^{\alpha-\alpha\eta}\, di\right]^{\frac{1+\alpha\eta-\alpha}{\eta-1}}}{\left\{\int \left(z_i^P z_i^T\right)^{\eta-1} (MPK_i)^{\alpha-1-\alpha\eta}\, di\right\}^{\alpha}}. \tag{24}$$

That is, the aggregate TFP in this economy is determined by firms' idiosyncratic productivity and the extent to which they are constrained. Note that the TFP here corresponds to the function $f(\phi)$ in our two-period model. The MPK here is $\frac{\alpha p_i y_i}{K_i}$, i.e., the true adjusted MPK.

To compute the efficient level of TFP given the set of firms that operate in the original economy, we consider the social planner who tries to maximize total output, subject to the total amount of utilized capital and labor already allocated to these firms. The solution to this problem requires that the MPK is equalized across firms, and the efficient level of TFP is given by:

$$\text{TFP}^{\text{e}} = \left(\int \left(z_i^P z_i^T\right)^{\eta-1} di\right)^{\frac{1}{\eta-1}}. \tag{25}$$

Hence, TFP losses from misallocation are:

$$\text{TFP losses } = \left(\int \left(z_i^P z_i^T\right)^{\eta-1} di\right)^{\frac{1}{\eta-1}} - \log \text{TFP}. \tag{26}$$

Further, if we assume that MPK_i and $z_i^P z_i^T$ are jointly log normal distributed, then Eq. (26) can be simplified to:

$$\text{TFP losses } = \frac{1}{2}\alpha(\alpha\eta + 1 - \alpha)\,\text{var}\left(\log MPK_i\right). \tag{27}$$

This equation indicates that TFP losses are increasing in MPK dispersion. Intuitively, the efficient allocations entail an equalization of MPK, and hence the dispersion in MPK results in TFP losses. The effect of misallocation on aggregate TFP also depends on the curvature in the production function, and the relative shares of capital and labor, as manifested in α and

η. Eq. (27) shows that MPK dispersion is a sufficient statistic to interpret efficiency losses given other standard parameters in this log-normal world, in line with Hsieh and Klenow (2009) and David, Schmid, and Zeke (2020).

5 Quantitative analysis in the dynamic model

In this section, we quantify the effect of leasing on mitigating capital misallocation and on improving aggregate efficiency. We start by discussing the data we use and present a set of novel empirical facts. These data moments are used to discipline our model and to evaluate the model parameterization. Next, we discuss the quantitative results, and then the transition dynamics.

5.1 Data

Our sample consists of annual Compustat data from 1977 to 2017 for US publicly listed firms. We exclude utility firms (Standard Industrial Classification (SIC) codes 4900–4999), finance firms (SIC codes 6000-6999), public administrative firms (SIC codes 9000-9999), as well as firms in the lessor industries (SIC code 7377 and industries whose SIC codes begin with 735 and 751). We then exclude firms with missing key variables and eliminate firms that are not incorporated in the US and/or do not report in US dollars. Appendix B provides more details. In the following, we mainly focus on two aspects: the data moments that highlight the importance of leased capital and the data moments on MPK dispersion.

5.1.1 Importance of leased capital

We follow Rampini and Viswanathan (2013), Rampini and Viswanathan (2020) and Lim, Mann, and Mihov (2017) to estimate the amount of leased capital. Specifically, a firm's leased capital in a year is its total rental expenses in that year multiplied by a factor 8. We denote this direct capitalized item as leased capital (multiplier).[24] We use Property, Plant, and Equipment - Total (Net), i.e., PPENT, to measure owned tangible capital and further define leased capital ratio as leased capital divided by the sum of leased and owned capital. Similarly, we define rental share as the ratio between rental expense over the sum of capital expenditure plus rental expense. The leased capital ratio and the rental share measure the proportion of total capital input in a firm's production obtained from leasing activity. We use total book assets (AT) to determine size groups. We measure the firm-level constraint by the Whited-Wu index (Whited and Wu (2006), Hansen et al. (2007), WW index hereafter).[25] Table 1 reports the summary statistics of leased capital ratio and leverage for the aggregate and for the cross-sectional firms in our sample.

[Place Table 1 about here]

At the aggregate level, leased capital accounts for a substantial portion (over 20%) of overall productive assets. Using rental share yields a slightly lower proportion of 18%. The magnitude is consistent with Eisfeldt and Rampini (2009) and Rauh and Sufi (2012). These observations serve as important evidence to illustrate how leased capital might be utilized in production. For leverage, considering leased capital increases its overall level by 40%.

In the cross-section, the average leased capital ratio of small firms (0.48) is significantly higher than that of large firms (0.22); that is to say, small firms lease more. Meanwhile, the average debt leverage of small firms (0.14) is lower than that of large firms (0.25). Defined as the sum of debt and rental leverage, the lease-adjusted leverage ratios across two different groups are comparable to each other. A similar pattern holds for financial-constraint-sorted

[24] Alternatively, the amount of leased capital can be proxied by the present value of current and future lease commitments, as in Rauh and Sufi (2012), Li, Whited, and Wu (2016), Graham, Lemmon, and Schallheim (1998), Cornaggia, Franzen, and Simin (2013), and Graham and Lin (2018). We discuss the construction of these alternative measures in Appendix B.2. Using these measures, we find similar patterns for the aggregate and for the cross-sectional firms, though the magnitudes differ slightly. Combining all different measures, we believe the reasonable take is that the leased capital and leased capital ratio are within the range estimated by different methods. See Table 11 in Section 7.2.

[25] The results are very similar when we use other financial constraint measures, such as the size-age (SA) index derived by Hadlock and Pierce (2010).

groups. These imply that leasing is an important source of external finance for small and financially constrained firms, and complements financial debt.

The facts on leased capital ratio are the first set of moments that we use to calibrate our model.[26] We will next present moments related to Hsieh and Klenow (2009) type of capital misallocation, which are the second set of moments that we are interested in.

5.1.2 Unadjusted and lease-adjusted MPK dispersion

In line with prior studies, we measure capital misallocation using MPK (in log) dispersion. Our discussions in the two-period model suggest that there is an overestimation of MPK and MPK dispersion when leased capital is utilized but ignored. This exactly happens under previous lease accounting procedure, in which leased capital is off-balance sheet and left as "unmeasured." Hence, prior literature, such as Hsieh and Klenow (2009) and Chen and Song (2013), doesn't correctly adjust MPK for leased capital.[27] Ignoring leased capital would overestimate the MPK. Intuitively, bringing back leased capital effectively narrows the divergence of MPKs, since small and financially constrained firms, which tend to have high (unadjusted) MPKs, lease more.

[Place Figure 4 about here]

To illustrate this point, we plot the kernel density estimates of MPK with and without lease-adjustment in Figure 4. The red line denotes the MPK under existing measures, following Chen and Song (2013) and the large literature. We denote it as the unadjusted measure. The blue line denotes the measure adjusted for leased capital. We use the model

[26] Our results in Table 1 are in line with Eisfeldt and Rampini (2009) and Rampini and Viswanathan (2013), who further show that ignoring leased capital brings significant bias in terms of a firm's investment, capital structure, and risk management; and this bias is asymmetric in that it is particularly severe for small and financially constrained firms.

[27] While the data source may be different (e.g., Chen and Song (2013) and David and Venkateswaran (2019) use firm-level data from Compustat, whereas Hsieh and Klenow (2009) use plant-level data from Census of Manufactures (CM)), none include leased capital in total fixed asset measurements. We discuss in detail why these existing measures are biased in Appendix C.4 using model guidance.

guidance to construct this adjusted measure.[28] We observe an obvious left shift of the mean for the adjusted measure, which indicates that the average MPK is overestimated without lease-adjustment. Meanwhile, the distribution of the adjusted measure is less spread out, suggesting that the measured MPK dispersion without lease-adjustment is also overestimated.

[Place Table 2 about here]

Table 2 further confirms our intuitions. In Row 1, we present the MPK dispersion under the existing unadjusted measure. The unadjusted MPK dispersion is 0.49, consistent with that in David, Hopenhayn, and Venkateswaran (2016) and David and Venkateswaran (2019).[29] We adjust for leased capital and report the adjusted MPK dispersion in Row 2. The adjusted MPK dispersion is 0.26. The difference between these two measures is 0.23, implying a 48% reduction. Moreover, this reduction is clearly more prominent in small and financially constrained firms, consistent with the fact that small and financially constrained firms rely heavily on leased capital.[30]

It is worth mentioning that, motivated by the insight in our aggregation results, this significant drop in MPK dispersion would translate into a 50% (or equivalently, 10 percentage points) reduction of measured TFP losses in the US economy, suggesting that the US economy is more efficient in capital allocation than previously expected.[31]

In sum, the empirical moments shown above include the leased capital ratio and MPK dispersion reduction after lease-adjustment. We omit discussions of other standard moments here. Now, we are ready to discuss how we utilize these moments for parameterization and model evaluation.

[28] The details can be found in Appendix C.4.

[29] To isolate the firm-specific variation in our data series, we extract a time-by-industry fixed-effect from each and use the residuals. Industries are classified at the SIC 4-digit level. This is equivalent to deviating each firm from the unweighted average within its industry in each period.

[30] We again utilize other measures of leased capital and find robust patterns in these results. See Section 7.2.2.

[31] We provide additional discussion of this in Appendix E.

5.2 Parameterization and model evaluation

5.2.1 Parameterization

Table 3 lists parameter values for our benchmark dynamic model. There are two types of parameters. First, we choose conventional values for eight parameters (β, α, δ, η, ν, λ_1, λ_0, and ρ) before solving the model. We assume a period length of one year. Similar to Gopinath et al. (2017), we assume that agents are fairly impatient and choose a value of β equal to 0.87. The capital share α in production is set equal to 0.37. We accordingly set the rate of depreciation to $\delta = 0.06$, consistent with Buera, Kaboski, and Shin (2011) and Midrigan and Xu (2014). The elasticity of substitution between firms η is set equal to 7.5, consistent with the range given by the trade and industrial organization literatures (which is typically from three to ten) (Broda and Weinstein, 2006; Hendel and Nevo, 2006). In order to feature incomplete markets and precautionary saving motives, we assume that the labor efficiency ν can be on and off.[32] The probability of remaining on (λ_1) and remaining off (λ_0) are chosen to be 0.9 and 0.7, respectively, so that we can match the employment to population ratio in the US. We choose the value of labor efficiency ν to ensure that the total labor supply is one. In the literature, there is little agreement about the persistence of the idiosyncratic shock process. Hence, we set ρ to be within the range of typical estimates/choices in prior studies (Clementi and Palazzo, 2016).

[Place Table 3 about here]

We next calibrate the remaining parameters. We choose collateralizability θ to match the leverage ratio, and choose h to match the leased capital ratio in the US, as presented in Table 1.[33] We pin down the standard deviation of the idiosyncratic shocks, σ_ϵ, by requiring

[32] An incomplete market means that the market-clearing interest rate is lower than $\frac{1}{\beta}$; that is, the user costs are linked to the lower interest rate, rather than the higher $\frac{1}{\beta}$.

[33] The monitoring cost h is in reduced form (i.e., a constant), and it incorporates other factors which makes leasing expensive, such as the additional adjustment cost associated with leasing. Nevertheless, our choice of h is reasonable in the sense that it allows us to match the data quite well.

that the model matches the volatility of the ratio of owned capital to total capital in the data. Eventually, we choose the variance of the permanent component, $var(z_i^P)$, to match the volatility of output.

5.2.2 Model evaluation

We now assess the quantitative performance of our model. By comparing key moments in the aggregate and in the cross-section, we document the success of our model to generate outcomes that resemble those observed in the data.

Aggregate moments We report the aggregate moments in Table 4. The first two rows in Panel A show that our model matches the average leased capital ratio and leverage by construction. With respect to MPK dispersion, we find that in the model, the unadjusted measure is about 0.23, whereas the adjusted one is 0.13. Both account for roughly 50% of their data counterparts. The difference between these two measures of MPK dispersion is 0.10 in the model, versus 0.23 in the data. In terms of percentage, the reduction in MPK dispersion after lease-adjustment is of similar magnitude between model and data - both around 45%.

[Place Table 4 about here]

It is natural that our model cannot generate all the observed MPK dispersion in the data, as we feature financial frictions as the only source in generating MPK dispersion.[34] In the data, there can be other sources of MPK dispersion, such as information frictions (David, Hopenhayn, and Venkateswaran, 2016), risk considerations (David, Schmid, and Zeke, 2020), and adjustment costs (Asker, Collard-Wexler, and De Loecker, 2014), among others. Nevertheless, the model-generated (unadjusted) MPK dispersion is reasonable, in line with the estimates induced by financial frictions in the literature.

[34] This helps us to focus solely on financial frictions and hence isolate their effects. It is also for parsimonious reasons.

In Panel B, we look at the statistics related to distributional moments in the data and in the benchmark model. Our model matches the variance of $\log(y)$ and $\log\left(\frac{K^o}{K^o+K^l}\right)$ by construction. Row 3 in Panel B shows that our model generates roughly 90% of the variance of $\log(K^o)$ observed in the data. The variance of $\log(L)$ is slightly larger than its data counterpart, but still within a reasonable range.

We report the last set of statistics in Panel C, which include autocorrelations and cross-sectional correlations of the variables of interest. Overall, the model fit is reasonably good for the autocorrelation relations. With respect to the (untargeted) cross-sectional moments, we find that they reproduce the negative relationship observed in the data, except the last two rows. However, the difference between these two rows roughly match the data.

Moments in the cross-section In Table 5, we simulate firms and sort them into groups based on firm size. This helps us better compare the cross-sectional distribution for the stationary economy with the data.

[**Place Table 5 about here**]

Panels A and B report the moments from the data and from the model simulation, respectively. We make the following observations. First, both our data and model imply that large firms have a significantly lower leased capital ratio than small firms. Second, and more importantly, we find that, consistent with the data, the difference of MPK dispersion between two measures presents a monotone pattern across firm groups sorted by size. The magnitudes (in terms of percentage) are also quantitatively comparable to the data.

In sum, the model-simulated data are broadly consistent with the basic features of the aggregate macro economy and of the cross-section of firms, though we deliberately keep the model structure simple and transparent.

5.3 Quantitative implications

Having documented the success of our model to match many aspects of firm-level behavior, we now present the quantitative implications of leasing on MPK dispersion and aggregate efficiency. We contrast our benchmark economy with the first-best allocation and with the economy without leasing, and then conduct a number of experiments by changing the key parameters.

Column (1) of Panel A in Table 6 presents the benchmark economy. The equilibrium interest rate is 2.5% to clear the asset market. As discussed before, our benchmark model generates reasonable magnitudes for the unadjusted and adjusted MPK dispersion. Then we apply Eq. (26) to quantify the implications of MPK dispersion on the aggregate efficiency. We find that the associated TFP losses are nearly 5% in our benchmark economy, relative to the first-best.

In Column (1) of Panel B, we artificially shut down the leasing market. Comparing these two economies in Panel A and Panel B, we find an obvious drop in interest rate in the economy without leasing. This is intuitive, because less asset will be supplied when the leasing market is shut down, which drags down the equilibrium interest rate. For MPK dispersion, both unadjusted and adjusted measures are clearly the same in the no-leasing economy. We observe that now MPK dispersion is 0.20, which is 50% higher than that (0.13) in the benchmark leasing economy. This is reflected in larger TFP losses from capital misallocation (9 %, relative to the first-best).[35] That is, shutting down the leasing market generates efficiency losses that are 4 percentage points higher (as shown in Column (1) of Panel C). In other words, the ability for firms to lease capital recovers approximately 50% of

[35]For a comparison, our estimate (when the leasing market is shut down) is within the same ballpark of prior studies (Buera, Kaboski, and Shin, 2011; Midrigan and Xu, 2014), though the magnitude of financial friction-induced misallocation in explaining the fall in TFP is somewhat mixed in the literature. Specifically, our estimate when the leasing market is shut down corresponds to numbers in the closed economy in Midrigan and Xu (2014). In addition, Gilchrist, Sim, and Zakrajšek (2013) use direct measures of firms' borrowing costs to infer TFP losses from financial frictions - on the order of about 4 percent. This number corresponds to (and matches) the TFP losses under our benchmark model with leasing, which is linked to the adjusted MPK dispersion measure.

efficiency losses caused by capital misallocation induced from financial frictions.

[**Place Table 6 about here**]

Role of collateralizability θ The remaining columns in Table 6 show the effect of reducing θ. In economies with leasing (Panel A), we find a clear declining pattern of leverage when financial constraints are tighter. This is intuitive as a tighter constraint forces firms to borrow less. The equilibrium interest rate also drops to clear the market. Next, we find that the unadjusted MPK dispersion monotonically goes up - from 0.04 when θ is 0.75 to 0.37 when θ is 0.1. Interestingly, the adjusted MPK dispersion does not necessarily go up; rather, it initially goes up, then goes down.[36] These patterns convey messages in the time series: since a low θ corresponds to bad times, our finding indicates that the leased capital ratio is countercyclical; and that the unadjusted MPK dispersion is more countercyclical than the adjusted one. This is consistent with our two-period model. We explore this further when analyzing the transition dynamics in Section 5.4.

Columns (2) to (6) of Panel B presents the set of quantitative results under different θs when we eliminate the leasing market. Comparing Panel A and Panel B, we first note that the aggregate implications of economies with and without leasing are very similar for extremely large values of θ (Column (2)). This is because financial frictions are minimal here and leasing already plays a negligible role in the original economy. Looking across other columns in these two panels, we observe that along with a declining θ, the drop in interest rate is more severe and the increase in MPK dispersion is larger in no-leasing economies. Without leasing, less loanable resources would be channeled back into production, and hence the drop in equilibrium interest rate becomes larger. Naturally, a lower interest rate requires a larger amount of capital stock for unconstrained firms, which makes it harder and more time-consuming for poor firms to catch up this optimal amount, resulting in larger capital

[36] In untabulated results, we consider a version in which firms face additional adjustment costs associated with leasing, which depend on their leased capital ratios. The adjusted MPK dispersion continues to go up, but the increase is lower than the increase of unadjusted MPK dispersion.

misallocation. This can be clearly seen from Panel B when θ drops. With the option to rent capital, this difficulty is alleviated since firms can lease to achieve a larger amount of total utilized capital, resulting in a lower magnitude of misallocation rise in Panel A (relative to Panel B). Finally, the difference in TFP losses under two economies (Panel B - Panel A) becomes larger when θ goes down, indicating that the ability to lease recovers a larger proportion of efficiency losses. This emphasizes a stronger mitigating role that leasing plays during recessions.

[**Place Table 7 about here**]

Role of the monitoring cost h In Table 7, we vary other key model parameters. Columns (2) and (3) show the statistics when the leasing fee varies, in which we increase or decrease the monitoring cost h.

In Panel A, we study economies with leasing. Clearly, as h increases, leasing becomes more expensive, and the leased capital ratio declines as a result. Higher leasing fees also manifest themselves in larger (adjusted and unadjusted) MPK dispersion. The adjusted misallocation increases from 0.13 in the benchmark economy to about 0.19 when the monitoring cost h is 0.3, and decreases to 0.05 when the monitoring cost reduces to 0.08. The unadjusted misallocation is 0.20 when $h = 0.3$, and is 0.36 when $h = 0.08$. We notice that the gap between unadjusted and adjusted MPK dispersion narrows when h becomes large, corresponding to the fact that less leased capital is utilized. With respect to TFP losses, our model generates greater TFP losses (i.e., five times larger) when $h = 0.3$ relative to when $h = 0.08$.

For counterfactual economies without leasing, we report the efficiency losses in Panel B. The comparison between two panels, which we report in Panel C, reveals that the mitigating role of leasing declines substantially when firms face a higher h. This finding has policy implications - policy tools that can effectively reduce the monitoring cost should be widely used, as they would foster a more developed leasing market and hence greatly alleviate the inefficiency induced from financial frictions.

Role of the persistence of shocks ρ The persistence of transitory productivity shocks also matters. For economies with leasing (Panel A in Table 7), Columns (4) and (5) suggest that a more persistent shock leads to higher leased capital ratios, larger MPK dispersion, and larger TFP losses. When the shock is more persistent, there will be more firms with higher financing needs, since it takes longer for firms to grow out of the borrowing constraints. Then capital misallocation persists and remains large. Therefore, leasing becomes more favorable. As more leased capital is associated with a higher ρ, the mismeasurement between unadjusted and adjusted MPK dispersion becomes larger. Next, we contrast each column in Panel A with their no-leasing counterpart (Panel B) and present the comparison in Panel C. We find that the difference in efficiency losses is larger for economies with higher ρ. That is, the ability for firms to lease capital is able to generate higher efficiency gains for economies with more persistent shocks.

Role of the volatility of productivity shocks σ_ϵ In Columns (6) and (7) of Table 7, we examine the role of the volatility of productivity shocks. In economies with leasing (Panel A), we find that, when we reduce volatility, the losses from misallocation are now smaller (2.2 percent) compared to those in our benchmark setup (4.7 percent). Intuitively, small changes in productivity generate less variations on capital and would less severely distort allocations. Consequently, leasing plays a less important role and will be less used. We do find a lower leased capital ratio (0.02) when σ_ϵ is half of that in the original benchmark economy. When compared to counterfactual cases with no leasing market (Panel B), we find that the difference in TFP losses decreases sharply when σ_ϵ becomes lower, indicating that only a small fraction of efficiency losses can be recovered by leasing under a low σ_ϵ.

5.4 Transition dynamics

Our analysis has focused on stationary equilibria. We now perform an analysis of the transition dynamics associated with unexpected changes in the collateralizability θ and the monitoring cost h. We consider the benchmark equilibrium as the initial condition and focus on an open-economy version of our model.[37] We first study a permanent unanticipated decrease of one standard deviation of θ (Case 1). We then analyze a scenario in which both θ and h are shocked (Case 2). That is, θ decreases by one standard deviation while h increases to infinity.[38]

Case 1 Figure 5 illustrates how our benchmark economy responds to a permanent decline in θ.[39] We note the following observations. First, after the shock, the leased capital ratio immediately rises and gradually moves to the new steady state level. This happens because the user cost of owned capital increases, which leads to a drop in firms' demand for owned capital. Meanwhile, the ability for the household to save through credit markets is weakened by a lower θ, which gives the household more incentives to save through the leasing market. Both channels suggest that leasing becomes more attractive after the credit tightening (i.e., leasing is countercyclical).

[Place Figure 5 about here]

Second, the unadjusted MPK dispersion sharply increases in the first years after the shock, whereas the adjusted MPK dispersion slightly drops. This pattern points out the fact that there exists a larger mismeasurement in measured MPK dispersion in bad times - i.e., the unadjusted MPK dispersion is more countercyclical than the adjusted one.

[37] We study an open-economy version for simplicity's sake. The qualitative implications of open and closed economies are very similar.

[38] We solve the model's transition dynamics using a shooting algorithm by iterating on the dynamics of the appropriate measures and equilibrium wage rates until convergence.

[39] We compute and infer the standard deviation of θ over the business cycle using the data from Ai et al. (2020).

Case 2 We next study the case where the monitoring cost h is lifted to infinitely large and the collateralizability θ is reduced by one standard deviation. It is obvious that the leased capital will be absent and that the MPK dispersion increases on impact.[40] The dispersion is reversed mildly and gradually (but not fully) in subsequent periods as producers accumulate internal funds.

Case 1 versus Case 2 We then compare the aggregate implications of the above two cases. Figure 6 displays the aggregate utilized capital and the TFP losses from misallocation, respectively. The total utilized capital is higher in the case with a single θ shock than that with a joint shock. This is intuitive as the case without h shock allows firms to relax tighter financial constraints and channel more resources back into production through leasing. In the right panel, the difference of two lines reflects the role of leasing in mitigating misallocation during credit tightening. We find that, quantitatively, the ability for firms to lease generates sizable TFP gains at roughly 4.5%.[41]

[Place Figure 6 about here]

6 Testable implications

So far, we have constructed a theory and quantify to what extent leasing mitigates capital misallocation. From the transition dynamics and equilibrium quantities discussed above, we see that our model generates rich testable implications for the cyclical pattern of leased capital ratio, unadjusted MPK dispersion, and adjusted MPK dispersion:

1. The leased capital ratio is countercyclical.
2. Adjusting for lease, the MPK dispersion becomes less countercyclical.

[40] MPK dispersion for both measures converge and remain the same afterwards.

[41] The quantitative estimates in an open economy are conservative and effectively provide a lower bound relative to a closed economy, because the effect of leasing on the interest rate is ignored.

The rest of this section uses both firm-level and aggregate data to provide direct evidence for these implications. We also provide suggestive causal evidence showing the mitigation effects that leasing has on capital misallocation induced by financial frictions.

6.1 Cyclical patterns of leased capital

To study the cyclical patterns of firms' leasing activities, we first investigate firm-level panel regressions. We again use annual Compustat data. We estimate the following equation:

$$LCR_{i,t} = d_i + \beta_g GDP_t + \beta_a A_t + \Gamma \mathbf{X_{it}} + u_{i,t}, \tag{28}$$

where i denotes a firm, t denotes a year, and $LCR_{i,t}$ is the variable of interest: the growth of leased capital ratio (i.e., first differencing). d_i denotes a firm fixed effect. GDP_t is the growth of real GDP at t (i.e., first differencing). A_t represents other aggregate variables, such as time-varying uncertainty in business conditions, which we proxy by the firm-level standard deviation of sales growth and asset growth. $\mathbf{X_{it}}$ consists of standard control variables, including the natural logarithm of total assets, dividend, tangibility, cash to income ratio, tax rate, and debt leverage.

[Place Table 8 about here]

We report our results in Table 8. We find that all specifications present negative and significant correlations between first-differenced leased capital ratio and first-differenced aggregate GDP. This emphasizes that leasing activities are indeed countercyclical.[42]

Next, we study the cyclical properties of the aggregate series. We focus on the cash-flow-based leased capital ratio (i.e., rental share) by computing the percentage of aggregate rental fees in total expenditure (sum of capital expenditure and rental fees) each year.[43] We plot

[42]In Section 7.2.1, we confirm the countercyclicality using different measures for firms' leased capital ratio.

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

the time series of the leased capital ratio in the top panel of Figure 7. In the bottom panel, we show the H-P filtered cyclical components of the leased capital ratio and output. The output data is published by the Federal Reserve Bank of St. Louis. The shaded areas in both panels indicate NBER-classified recessions. Clearly, whenever there is a recession, the leased capital ratio rises. The leased capital ratio exhibits strong countercyclicality, with a correlation of -0.50 (t-stat$= -3.25$) with output. A similar conclusion has been documented in Gal and Pinter (2017) and Zhang (2012).

[Place Figure 7 about here]

To conclude, we find that the countercylical pattern of leasing is robust to different aggregation levels, to different time-series filtering methods (i.e., HP-filter or first differencing), and to different measures of leased capital ratio that we use. Li and Yu (2021) use our evidence extensively documented here as motivating facts for their paper.

6.2 Cyclical patterns of adjusted MPK dispersion

It is well documented in Eisfeldt and Rampini (2006) and Ai, Li, and Yang (2020) that the cross-sectional dispersion of MPK is countercyclical. The countercylicality of leased capital ratio, however, suggests that adjusting for leased capital leads to significant implications in the measured MPK dispersion. This is because the lease-adjusted MPK dispersion is a joint product of the unadjusted MPK dispersion and leased capital ratio dispersion, as can be seen from Eq. (18) in our two-period model. During bad times when there is a large dispersion in unadjusted MPK dispersion, the countercyclical leasing behavior will bring a procyclical term, weakening the countercyclicality of unadjusted MPK dispersion. The less countercyclical pattern of lease-adjusted MPK dispersion is also confirmed in the analysis of our dynamic model and the transition dynamics. We test this implication in this part.

[Place Table 9 about here]

In Table 9, we report the correlation of MPK dispersion with output. At the aggregate level, the lease-adjusted MPK dispersion is acyclical: though the correlation with output is negative, it is insignificant. The weakening effect on countercyclical MPK dispersion is more salient among small and financially constrained firms, within which the correlation coefficients are closer to 0.

6.3 Causal evidence

We now provide causal evidence on the mitigating role of operating leases for capital misallocation induced by financial frictions. Due to space limitations, all tables and detailed economic interpretations are provided in Appendix F.

Through exploiting exogenous variation from the passage of anti-recharacterization laws, we show that the anti-recharacterization laws, which increase secured lenders' ability to repossess collateral assets in bankruptcy, reduce capital misallocation for affected states in the US. More importantly, we find that such reduction in capital misallocation are smallest for firms with more access to the leasing market, suggesting that the ability to lease acts as a substitute for the policy shocks to reduce misallocation prior to the shocks.

Our results are robust when we include firm fixed effect, year fixed effect, and firm-level controls, including the natural logarithm of total assets, dividend, tangibility, cash to income ratio, tax rate, and debt leverage. Also, our results are robust to using either the adjusted or unadjusted MPK, and to different proxies for firms' accessibility to the leasing market. All told, the empirical finding on heterogeneity by ex-ante leasing access strongly supports our theory that leasing indeed provides an important mitigation to misallocation caused by financial frictions.

In summary, our empirical evidence documents a highly countercyclical feature of leased capital, and less countercyclical patterns of capital misallocation. Our results provide additional caveat to prior literature on capital misallocation (Eisfeldt and Rampini, 2006; Ai, Li, and Yang, 2020), and highlight the mitigation effects that leasing has on capital misallocation. All the evidence is in line with our theory.

7 Additional empirical analyses

This section provides additional empirical analyses, including the sensitivity check with respect to the elasticity of substitution between owned and leased capital, additional results using other measures of leased capital, as well as the validation test using data after lease accounting rule change.

7.1 Sensitivity

We now briefly discuss the sensitivity of our empirical results with respect to the elasticity of substitution between owned and leased capital. Previously, we follow the literature (e.g., Eisfeldt and Rampini (2009) and Rampini and Viswanathan (2013)) and use the perfect substitutability assumption between these two types of capital. Here, we instead define the total utilized physical capital of a firm as a CES bundle of owned and leased capital: $K_{it}^{CES} = \left[\alpha_k K_{it}^{o\,\frac{\gamma-1}{\gamma}} + (1-\alpha_k) K_{it}^{l\,\frac{\gamma-1}{\gamma}}\right]^{\frac{\gamma}{\gamma-1}}$. Then, the lease-adjusted MPK takes a more general form as $\frac{\alpha p_{it} y_{it}}{K_{it}^{CES}}$.

We assign a wide range of γ and re-calculate the lease-adjusted MPK dispersion and its correlation with output. When γ goes to infinity, we obtain the perfect substitutability case. Table 10 reports our results when γ is equal to 2, 5, 10, and 15, respectively.[44] We find that choosing different values for the elasticity between owned and leased capital has a negligible effect on the level of adjusted MPK dispersion and its cyclical patterns.

[Place Table 10 about here]

In Appendix G, we provide additional evidence by directly estimating this elasticity in

[44]The choice of 10 is motivated by Gal and Pinter (2017).

the data. Our results suggest a high estimate, which favors our perfect substitutability assumption between owned and leased capital. In practice, after the lease accounting rule change (ASC 842 and IFRS 16) in 2019, firms are required to recognize operating lease-induced assets (right-of-use assets, ROUANT) on the balance sheets, and firms' fixed assets (PPENT) now include "Lease right-of-use asset" with an assumption of perfect substitution. Appendix A.2 provides more instituitional details about this and Section 7.3 uses such newly-available data.

In sum, the perfect substitution assumption is reasonable and innocuous, given the evidence that we find in the data, the practical treatment, as well as the theoretical results in prior studies (Eisfeldt and Rampini, 2009; Rampini and Viswanathan, 2013; Rampini, 2019).

7.2 Alternative measures of leased capital

We discuss other common empirical proxies for the capital amount of operating leases in this section. These measures rely on a discounting method, in which the leased capital is equal to the present value of current and future lease commitments. The difference lies in the numerators as well as the denominators. Appendix B.2 contains the detailed construction.

7.2.1 Leased capital ratio across different methodologies

Table 11 reports the summary statistics of leased capital ratio across different methodologies for the same sample in Table 1. Overall, we find consistent patterns of leased capital ratios for the aggregate and for the cross-sectional firms, sorted by firm size and firm-level constraint by the WW index.[45]

[45] It is noteworthy to mention the magnitudes. The leased capital ratio (multiplier) tends to give slightly larger magnitudes, whereas the rest based on future lease commitments are within the same ballpark. In fact, there have been debates in the literature about the potential discrepancy in magnitudes across different methods. As emphasized in Eisfeldt and Rampini (2009), using lease commitments usually leads to a lower bound of leased capital estimation since lease commitments are a lower bound on obligations, do not account for lease renewals, and often have many missing observations. Therefore, we believe the reasonable take is that the leased capital and leased capital ratio are within the range estimated by different methods we describe here.

[Place Table 11 about here]

Table 12 shows the cyclical pattern of firms' leasing activities under these measures of leased capital. We employ the specification in Eq. (28) and find a consistently negative and significant correlation between leased capital and output. These results confirm that leased capital ratio is countercyclical.

[Place Table 12 about here]

7.2.2 MPK dispersion across different leased capital proxies

We also check the robustness of our empirical results on (unadjusted and adjusted) MPK dispersion and the cyclical patterns when using other measures of leased capital. These results are presented in Table 13. We find that our results are robust, i.e., 1) under different measures of leased capital, there is always a large reduction in the level of MPK dispersion after lease-adjustment, ; and 2) the adjusted MPK dispersion becomes less countercyclical for different measures of leased capital.

[Place Table 13 about here]

7.3 Validation

7.3.1 Validation of leased capital calculation

To further validate our calculations of leased capital, we construct an alternative measure of leased capital ratio **after** the lease accounting rule change. We focus on the period of 2019 to 2021 during which the new accounting rule applies. The alternative measure of leased capital capital is defined as the firms' self-reported lease right-of-use asset (ROUANT) divided by property, plant, and equipment (PPENT). Note that for this period, operating lease-induced assets are directly added to PPENT, hence the owned capital is equal to (PPENT

- ROUANT). We compare the leased capital ratio based on this self-reported amount with ratios constructed using the common approximation methods discussed earlier. We report the comparisons for the overlapping sample in Table 14.

[Place Table 14 about here]

On average, we find that the values of leased capital estimated by common methods used in prior studies are comparable to the value newly-reported by firms.[46] Hence, they validate the proxies for leased capital in our sample before the accounting rule change (i.e., pre-ASC 842). They also echo the point that the perfect substitution assumption between two types of capital used throughout this paper is reasonable.

7.3.2 Validation of MPK dispersion after lease accounting rule change

To validate the comparison between (unadjusted and adjusted) MPK dispersion, we also focus on the period of 2019 to 2021 during which the new accounting rule applies. We compare the MPK dispersion under the measure based on ROUANT with those under other commonly used empirical measures of leased capital during the same period.

[Place Table 15 about here]

As shown in Table 15, we observe that after the lease accounting rule change, the reduction in MPK dispersion after lease-adjustment is consistent across different measures of leased capital - around 40% The percentage difference is also in line with the results in our original sample. This validates our calculation and confirms the robustness of our results.

[46] With respect to the potential difference across these approaches, a similar argument applies - that using lease commitments usually leads to a lower bound (Eisfeldt and Rampini, 2009), and we tend to think the leased capital ratio is within a narrow range.

8 Conclusion

As an important proportion of productive assets, leased capital has been largely ignored in the macro-finance literature, due to the fact that it does not show up on firms' balance sheets under previous lease accounting standards. We empirically document that leased capital accounts for around 20% of the total productive physical assets among US publicly listed firms, and this proportion is more than 40% for small and financially constrained firms. We explicitly introduce this key element into a dynamic general equilibrium model of capital misallocation with heterogeneous firms facing collateral constraints. In contrast to a counterfactual no-leasing economy, we show analytically that allowing firms to lease capital mitigates capital misallocation and hence improves aggregate efficiency. When calibrated to the US data, our model economy indicates a quantitatively sizable mitigation effect of leasing on financial friction-induced capital misallocation.

Furthermore, our model offers guidance on the empirical measurement of capital misallocation (i.e., dispersion in marginal products of capital (MPK) (Hsieh and Klenow, 2009)) - there exist overestimations in the level and the cyclicality of capital misallocation when leased capital is ignored. By utilizing firm-level data, we find supporting evidence: (1) considering leased capital will substantially reduce the observed MPK dispersion in the US by nearly 50%, as compared to David, Schmid, and Zeke (2020) and David and Venkateswaran (2019), among others; and (2) explicitly accounting for leased capital will correct the overestimation of countercyclical patterns of MPK dispersion (Ai, Li, and Yang, 2020). We also provide suggestive causal evidence to support our theory.

In summary, our paper highlights that, from both theoretical and empirical perspectives, leasing serves as an additional allocation channel and mitigates capital misallocation induced by credit constraints. Our findings suggest that future research should take leasing into account when analyzing credit constraints and their impact on the allocation of capital.

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Tables and Figures

Table 1

SUMMARY STATISTICS

	Aggregate	Size			WW index		
Variables	**Mean**	**S**	**M**	**L**	**C**	**MC**	**UC**
Leased capital ratio (multiplier)	0.24	0.48	0.40	0.22	0.49	0.40	0.22
Rental share	0.18	0.31	0.28	0.17	0.32	0.27	0.17
Debt leverage	0.25	0.14	0.20	0.25	0.17	0.22	0.25
Lease-adjusted leverage	0.35	0.33	0.37	0.34	0.37	0.38	0.34

This table presents summary statistics for variables of interest in our sample. Leased capital ratio is the ratio of leased capital over the sum of leased capital and owned capital (PPENT). Leased capital (multiplier) is defined as eight times the rental expense (XRENT), following Rampini and Viswanathan (2013), Rampini and Viswanathan (2020) and Lim, Mann, and Mihov (2017). Rental share is defined as the ratio between rental expense over the sum of capital expenditure (CAPX) plus rental expense. Debt leverage is the ratio of the sum of long-term debt (DLTT) and debt in current liabilities (DLC) over the sum of leased capital and total assets (AT). Lease-adjusted leverage is the sum of debt leverage and rental leverage, the latter of which is defined as the ratio of leased capital (multiplier) over the sum of leased capital and total assets (AT). On the right panel, we split the whole sample into subgroups according to their size, and by financial constraint level each year. Size is defined by total assets, while the financial constraint level is classified by the WW index, according to Whited and Wu (2006). We use "S," "M," and "L" to denote small, medium, and large firm groups, respectively. We use "UC," "MC," and "C" to denote unconstrained, mildly constrained, and constrained firm groups, respectively. We report time series averages of the cross-section averages in the table. The sample is from 1977 to 2017 and excludes financial, utility, public administrative, and lessor industries from the analysis. Firms that are not incorporated in the US and/or do not report in US dollars are also eliminated.

Table 2

MPK DISPERSION (UNADJUSTED VS. ADJUSTED)

	Aggregate	Size			WW index		
Variables	**Mean**	**S**	**M**	**L**	**C**	**MC**	**UC**
mpk dispersion- unadjusted	0.49	0.70	0.46	0.31	0.69	0.44	0.29
mpk dispersion- adjusted	0.26	0.33	0.25	0.18	0.32	0.24	0.17
Level diff.	-0.23	-0.37	-0.21	-0.13	-0.37	-0.20	-0.12
Percentage diff.	-48%	-53%	-46%	-42%	-53%	-45%	-41%

This table presents the time series averages of *mpk* ($\log(MPK)$) dispersion in our sample. Dispersion is defined as the cross-sectional variance. We subtract each *mpk* from its industry and year mean and work on the residuals. The unadjusted *mpk* is defined as the log difference between operating income (OIBDP) and owned capital (PPENT), while the adjusted *mpk* is defined as the log difference between adjusted operating income (OIBDP+XRENT) and the sum of owned capital and leased capital. On the right panel, we split the whole sample into subgroups according to their size and financial constrained level each year. Size is defined by total assets, while the financial constraint level is classified by the WW index, according to Whited and Wu (2006). We use "S," "M," and "L" to denote small, medium, and large firm groups, respectively. We use "UC," "MC," and "C" to denote unconstrained, mildly constrained, and constrained firm groups, respectively. We report time series averages in the table. The sample is from 1977 to 2017 and excludes financial, utility, public administrative, and lessor industries from the analysis. Firms that are not incorporated in the US and/or do not report in US dollars are also eliminated.

Table 3

PARAMETER VALUES IN THE DYNAMIC MODEL

Description	Parameter	Value
Discount factor	β	0.87
Capital share	α	0.37
Capital depreciation	δ	0.06
Elasticity of substitution	η	7.45
Labor efficiency	ν	1.30
Persistence unit worker state	λ_1	0.91
Persistence zero worker state	λ_0	0.70
Collateralizability	θ	0.30
Persistence of idiosyncratic transitory shocks	ρ	0.85
Std. dev. of idiosyncratic transitory shocks	σ_ϵ	0.85
Variance of exogenous permanent component	$var(z_i^P)$	0.47
Monitoring cost	h	0.16

This table reports the parameter values we used in the calibration procedure. We calibrate the model at annual frequency.

Table 4

MOMENTS: DATA VS. MODEL

Variables	**Data**	**Model**
Panel A: Main moments		
Leased capital ratio *(Targeted)*	0.11 to 0.24	0.14
Debt leverage *(Targeted)*	0.25	0.25
mpk dispersion - unadjusted	0.49	0.23
mpk dispersion - adjusted	0.26 to 0.28	0.13
Level diff. in mpk dispersion	-0.21 to -0.23	-0.10
Percentage diff. in mpk dispersion	-43% to -48%	-43%
Panel B: Distributional moments		
$\text{var}(\log(y))$ *(Targeted)*	2.28	2.28
$\text{var}\left(\log\left(\frac{K^o}{K^o+K^l}\right)\right)$ *(Targeted)*	0.15	0.15
$\text{var}(\log(K^o))$	2.56	2.13
$\text{var}(\log(L))$	1.96	2.28
Panel C: Correlation moments		
Autocorrelation of $(\log(y))$	0.95	0.95
Autocorrelation of $(\log(K^o))$	0.96	0.98
Autocorrelation of $\left(\log\left(\frac{K^o}{K^o+K^l}\right)\right)$	0.88	0.59
Autocorrelation of $(\log(L))$	0.97	0.95
Correlation of $\left(\log(K^o), \log\left(MPK^{unadj}\right)\right)$	-0.24	-0.17
Correlation of $\left(\log(K^o), \log\left(MPK^{adj}\right)\right)$	-0.06	-0.13
Correlation of $\left(\log\left(\frac{K^o}{K^o+K^l}\right), \log\left(MPK^{unadj}\right)\right)$	-0.39	-0.75
Correlation of $\left(\log\left(\frac{K^o}{K^o+K^l}\right), \log\left(MPK^{adj}\right)\right)$	0.04	-0.44

This table reports the moments in the data and from the model simulation. The "Data" column reports the empirical moments, in which we have considered moments under different leased capital proxies, as presented in Section 7.2. The "Model" column reports the model-implied moments. We simulate the economy at annual frequency, based on the calibration parameters in Table 3.

Table 5

CROSS SECTIONAL MOMENTS

Variables	**S**	**M**	**L**
		Panel A: Data	
Leased capital ratio	0.29 to 0.48	0.23 to 0.40	0.10 to 0.22
Level diff. in *mpk* dispersion	-0.37	-0.21	-0.13
Percentage Diff. in *mpk* dispersion	-53%	-46%	-42%
		Panel B: Model	
Leased capital ratio	0.31	0.20	0.11
Level diff. in *mpk* dispersion	-0.16	-0.09	-0.05
Percentage diff. in *mpk* dispersion	-55%	-40%	-29%

This table reports the moments across three size groups in the data and from the model simulation. Panel A reports the sorting results in the data, while Panel B reports the sorting results for simulated firms. We use "S," "M," and "L" to denote small, medium, and large groups, respectively.

Table 6

DYNAMIC MODEL IMPLICATIONS

Panel A: Model with leasing							
		(1)	(2)	(3)	(4)	(5)	(6)
Variables	Data	Benchmark	$\theta = 0.75$	$\theta = 0.55$	$\theta = 0.4$	$\theta = 0.25$	$\theta = 0.1$
Interest rate	2%	2.47	7.54	5.40	3.61	2.01	1.15
Leverage	0.25	0.25	0.48	0.39	0.32	0.21	0.08
mpk dispersion - unadjusted	0.49	0.23	0.04	0.11	0.18	0.27	0.37
mpk dispersion - adjusted	0.26	0.13	0.04	0.09	0.12	0.13	0.12
TFP losses, percent		4.70	2.56	4.50	5.02	4.37	3.26
Panel B: Shut down leasing							
		(1)	(2)	(3)	(4)	(5)	(6)
Variables		Benchmark θ	$\theta = 0.75$	$\theta = 0.55$	$\theta = 0.4$	$\theta = 0.25$	$\theta = 0.1$
Interest rate		0.23	7.53	5.28	2.94	-2.70	-6.00
Leverage		0.29	0.49	0.40	0.34	0.25	0.10
mpk dispersion - unadjusted		0.20	0.04	0.10	0.16	0.21	0.22
mpk dispersion - adjusted		0.20	0.04	0.10	0.16	0.21	0.22
TFP losses, percent		8.86	2.75	5.50	7.57	9.33	9.44
Panel C: Panel A vs. Panel B							
Diff in TFP losses		4.16	0.19	1.00	2.55	4.96	6.18

This table reports the implications of our model simulations. For comparison, we include the "Data" column, which corresponds to the empirical moments. Columns (1)-(6) correspond to models under benchmark parameters, as well as models under different values of the collateralizability parameter θ. Panel A shows the model economy with leasing, whereas Panel B shows the model economy without leasing. Panel C presents the comparison between Panel A and Panel B.

Table 7

DYNAMIC MODEL IMPLICATIONS OF ALTERNATIVE PARAMETERS

Panel A: Model with leasing								
		(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variables	Data	Benchmark	$h = 0.3$	$h = 0.08$	$\rho = 0.95$	$\rho = 0.3$	1.5xσ_ϵ	0.5xσ_ϵ
Interest rate	2%	2.47	0.34	5.75	1.70	1.78	1.85	1.15
Leverage	0.25	0.25	0.29	0.13	0.20	0.30	0.10	0.30
Leased capital ratio	0.11-0.24	0.15	0.01	0.37	0.17	0.06	0.28	0.02
mpk dispersion - unadjusted	0.49	0.24	0.20	0.36	0.36	0.10	0.49	0.05
mpk dispersion - adjusted	0.26	0.13	0.19	0.05	0.17	0.07	0.19	0.05
TFP losses, percent		4.70	8.29	1.38	5.04	3.11	5.30	2.16
Panel B: Shut down leasing								
TFP losses, percent		8.86	8.86	8.86	12.29	4.15	17.90	2.51
Panel C: Panel A vs. Panel B								
Diff in TFP losses		4.16	0.57	7.48	7.25	1.04	12.60	0.35

This table reports the implications of our model simulations under alternative parameters of the monitoring cost h, the persistence of the idiosyncratic transitory shock ρ, and the standard deviation of the idiosyncratic transitory shock σ_ϵ. For comparison, we include the "Data" column, which corresponds to the empirical moments. Columns (1)-(6) correspond to models under benchmark parameters, as well as models under alternative values of h, ρ, and σ_ϵ. Panel A shows the model economy with leasing, whereas Panel B shows the model economy without leasing. Panel C presents the comparison of TFP losses between Panel A and Panel B.

Table 8

LEASED CAPITAL: FIRM-LEVEL REGRESSION RESULTS

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
GDP growth	-0.44***	-0.52***	-0.57***	-0.28***	-0.36***	-0.44***
	(-8.04)	(-9.23)	(-9.54)	(-4.77)	(-6.11)	(-7.09)
SD of sales growth		0.19***			0.24***	
		(6.03)			(6.79)	
SD of asset growth			0.13***			0.17***
			(5.19)			(6.66)
Controls	No	No	No	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of observations	71,627	71,627	71,627	63,703	63,703	63,703
Within R-sq	0.001	0.002	0.002	0.008	0.009	0.009

This table presents results of firm-level panel regressions with the specification in Eq. (28). In Columns (1) to (6), the dependent variable is the leased capital ratio (multiplier). An observation is a firm-year. Standard errors are two-way clustered by firm and industry-year. *t*-statistics are in parentheses. *, **, and *** denote 10, 5, and 1% statistical significance, respectively. The sample is from 1977 to 2017 and excludes financial, utility, public administrative, and lessor industries from the analysis. Firms that are not incorporated in the US and/or do not report in US dollars are also eliminated.

Table 9

CORRELATION OF OUTPUT WITH MPK DISPERSION (UNADJUSTED VS. ADJUSTED)

Correlation of output with		Size			WW index		
Variables	**Aggregate**	**S**	**M**	**L**	**C**	**MC**	**UC**
mpk dispersion- unadjusted	-0.56	-0.42	-0.40	-0.51	-0.42	-0.36	-0.45
t-stat	-3.62	-2.19	-1.94	-3.44	-2.18	-1.81	-2.83
mpk dispersion- adjusted	-0.32	-0.18	-0.28	-0.30	-0.23	-0.20	-0.31
t-stat	-1.37	-0.72	-1.20	-1.63	-0.98	-0.86	-1.58

This table presents the correlation of output with *mpk* ($\log(MPK)$) dispersion. Deviations from trend are computed using the Hodrick and Prescott (1997) filter (H-P filter). The time series of the unadjusted *mpk* dispersion is computed as the cross-sectional variance of the unadjusted *mpk*, after controlling for industry and year fixed effect. The time series of the adjusted *mpk* dispersion is computed as the cross-sectional variance of the adjusted *mpk*, after controlling for industry and year fixed effect. Output is the log GDP series obtained from the Federal Reserve Bank of St. Louis. Standard errors are corrected for heteroscedasticity and autocorrelation of the residuals à la Newey and West (1987) and are computed using a GMM approach adapted from the Hansen, Heaton, and Ogaki GAUSS programs. Size is defined by total assets, while the financial constraint level is classified by the WW index, according to Whited and Wu (2006). We use "S," "M," and "L" to denote small, medium, and large firm groups, respectively. We use "UC," "MC," and "C" to denote unconstrained, mildly constrained, and constrained firm groups, respectively.

Table 10

EMPIRICAL RESULTS - SENSITIVITY CHECK

Panel A: *mpk* dispersion level					
Variables	$\gamma = \infty$	γ=**2**	γ=**5**	γ=**10**	γ=**15**
mpk dispersion- unadjusted			0.49		
mpk dispersion- adjusted	0.26	0.26	0.25	0.26	0.26
Level diff.	-0.23	-0.24	-0.24	-0.24	-0.24
Percentage diff.	-47.8%	-48.3%	-48.3%	-48.1%	-48.0%
Panel B: Correlation of GDP with					
mpk dispersion- unadjusted			-0.56		
t-stat			-3.62		
mpk dispersion- adjusted	-0.32	-0.37	-0.33	-0.33	-0.32
t-stat	-1.37	-1.62	-1.39	-1.45	-1.38

This table provides the sensitivity analysis of our empirical facts on MPK dispersion (level and cyclical patterns) with respect to the elasticity of substitution γ between owned capital and leased capital. In Panel A, we report the time series average of *mpk* ($\log(MPK)$) dispersion, whereas in Panel B, we report the correlation of output with *mpk* dispersion. For a detailed definition of the variables, see the description in Table 2 and Table 9. The only difference is that the denominator of the adjusted MPK is replaced by a CES form of owned capital and leased capital. The sample is from 1977 to 2017 and excludes financial, utility, public administrative, and lessor industries from the analysis. Firms that are not incorporated in the US and/or do not report in US dollars are also eliminated.

Table 11

SUMMARY STATISTICS FOR LEASED CAPITAL RATIO - ALTERNATIVE MEASURES

	Aggregate	**Size**			**WW index**		
Leased capital ratio	**Mean**	**S**	**M**	**L**	**C**	**MC**	**UC**
multiplier	0.24	0.48	0.40	0.22	0.49	0.40	0.22
commitment 1	0.14	0.32	0.26	0.13	0.33	0.26	0.12
commitment 2	0.13	0.32	0.26	0.12	0.33	0.26	0.12
commitment 3	0.11	0.29	0.23	0.10	0.30	0.23	0.10
commitment 4	0.13	0.30	0.24	0.12	0.32	0.24	0.11
commitment 5	0.13	0.29	0.24	0.12	0.30	0.24	0.12

This table presents summary statistics for leased capital ratio, under different measures of leased capital. Leased capital ratio is the ratio of leased capital over the sum of leased capital and owned capital (PPENT). Each row denotes a commonly used method for estimating leased capital. For a detailed description of these methods, please see Appendix B.2. On the right panel, we split the whole sample into subgroups according to their size, and by financial constraint level each year. Size is defined by total assets, while the financial constraint level is classified by the WW index, according to Whited and Wu (2006). We use "S," "M," and "L" to denote small, medium, and large firm groups, respectively. We use "UC," "MC," and "C" to denote unconstrained, mildly constrained, and constrained firm groups, respectively. We report time series averages of the cross section averages in the table. The sample is from 1977 to 2017 and excludes financial, utility, public administrative, and lessor industries from the analysis. Firms that are not incorporated in the US and/or do not report in US dollars are also eliminated.

Table 12

LEASED CAPITAL: FIRM-LEVEL REGRESSION RESULTS - ALTERNATIVE MEASURES

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
GDP growth	-0.42***	-0.41***	-0.43***	-0.24***	-0.27***	-2.34***
	(-5.61)	(-5.59)	(-5.86)	(-3.23)	(-3.60)	(-16.79)
SD of sales growth	0.50***	0.50***	0.41***	0.41***	0.41***	1.18***
	(10.95)	(11.09)	(9.23)	(9.33)	(8.95)	(16.8)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of observations	61,186	60,958	61,191	60,959	61,161	63,574
Within R-sq	0.006	0.006	0.006	0.006	0.006	0.025

This table presents results of firm-level panel regressions with the specification in Eq. (28), under different measures of leased capital. In Columns (1) to (6), the dependent variable is leased capital ratio (commitment 1), leased capital ratio (commitment 2), leased capital ratio (commitment 3), leased capital ratio (commitment 4), leased capital ratio (commitment 5), and rental share, respectively. For a detailed description of these estimating methods for leased capital, please see Appendix B.2. An observation is a firm-year. Standard errors are two-way clustered by firm and industry-year. t-statistics are in parentheses. *, **, and *** denote 10, 5, and 1% statistical significance, respectively. The sample is from 1977 to 2017 and excludes financial, utility, public administrative, and lessor industries from the analysis. Firms that are not incorporated in the US and/or do not report in US dollars are also eliminated.

Table 13

MPK DISPERSION (UNADJUSTED VS. ADJUSTED) - ALTERNATIVE MEASURES

Panel A: *mpk* dispersion level						
Variables	**multiplier**	**commitment 1**	**commitment 2**	**commitment 3**	**commitment 4**	**commitment 5**
mpk dispersion- unadjusted				0.490		
mpk dispersion- adjusted	0.256	0.272	0.270	0.268	0.270	0.277
Level Diff.	-0.234	-0.220	-0.219	-0.223	-0.221	-0.214
Percentage Diff.	-47.8%	-44.8%	-44.6%	-45.4%	-45.0%	-43.5%
Panel B: Correlation of GDP with						
mpk dispersion- unadjusted				-0.56		
t-stat				-3.62		
mpk dispersion- adjusted	-0.32	-0.38	-0.40	-0.40	-0.38	-0.40
t-stat	-1.37	-1.73	-1.84	-1.82	-1.69	-1.82

This table presents the time series average of *mpk* ($\log(MPK)$) dispersion in our sample, under different measures of leased capital. Dispersion is defined as the cross-sectional variance. We subtract each *mpk* from its industry and year mean and work on the residuals. The unadjusted *mpk* is defined as the log difference between operating income (OIBDP) and owned capital (PPENT), while the adjusted *mpk* is defined as the log difference between adjusted operating income (OIBDP+XRENT) and the sum of owned capital and leased capital. Each column denotes a commonly used method for estimating leased capital. For a detailed description of these methods, please see Appendix B.2. We report time series averages in the table. The sample is from 1977 to 2017 and excludes financial, utility, public administrative, and lessor industries from the analysis. Firms that are not incorporated in the US and/or do not report in US dollars are also eliminated.

Table 14

SUMMARY STATISTICS FOR LEASED CAPITAL RATIO - VALIDATION

	Aggregate	Size			WW index		
Leased capital ratio	**Mean**	**S**	**M**	**L**	**C**	**MC**	**UC**
ASC 842	0.14	0.28	0.19	0.13	0.29	0.19	0.12
multiplier	0.28	0.47	0.36	0.27	0.48	0.36	0.27
commitment 1	0.18	0.35	0.25	0.18	0.35	0.25	0.18
commitment 2	0.18	0.39	0.26	0.18	0.39	0.26	0.18
commitment 3	0.14	0.29	0.20	0.13	0.30	0.20	0.14
commitment 4	0.15	0.31	0.21	0.15	0.32	0.21	0.15
commitment 5	0.19	0.36	0.25	0.18	0.37	0.25	0.19

This table presents summary statistics for leased capital ratio, under different measures of leased capital after the lease accounting rule change. Compustat item PPENT now includes lease right-of-use asset (ROUANT). Leased capital ratio is the ratio of leased capital over total utilized capital, which is calculated as Compustat item PPENT minus ROUANT plus leased capital calculated using the following measures. Each row denotes a commonly used method for estimating leased capital. Leased capital (ASC 842) uses the lease right-of-use asset item (ROUANT) directly reported from Compustat after the lease accounting rule change. For a detailed description of the rest methods, please see Appendix B.2. On the right panel, we split the whole sample into subgroups according to their size, and by financial constraint level each year. Size is defined by total assets, while the financial constraint level is classified by the WW index, according to Whited and Wu (2006). We use "S," "M," and "L" to denote small, medium, and large firm groups, respectively. We use "UC," "MC," and "C" to denote unconstrained, mildly constrained, and constrained firm groups, respectively. We report time series averages of the cross section averages in the table. The sample is from 2019 to 2021 and excludes financial, utility, public administrative, and lessor industries from the analysis. Firms that are not incorporated in the US and/or do not report in US dollars are also eliminated.

Table 15

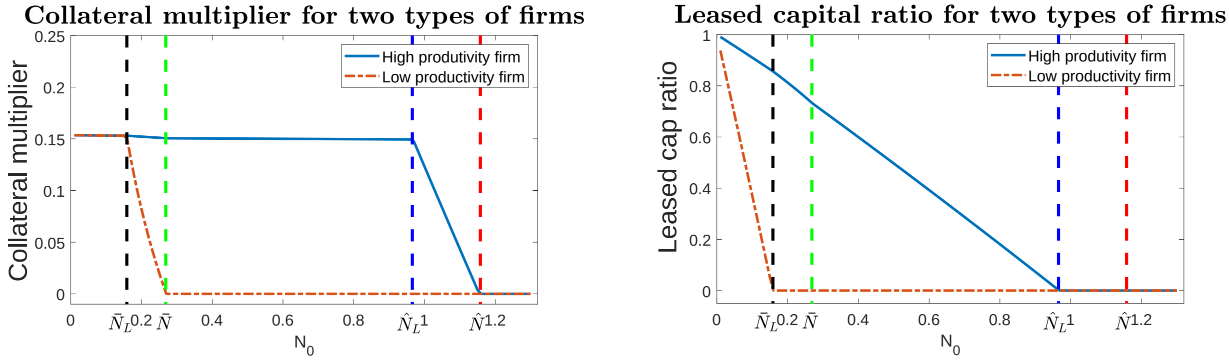
MPK DISPERSION (UNADJUSTED VS. ADJUSTED) - VALIDATION

Leased capital	*mpk* dispersion- unadjusted	*mpk* dispersion- adjusted	Level Diff.	Percentage Diff.
ASC 842	0.61	0.38	-0.23	-38%
multiplier	0.61	0.32	-0.29	-48%
commitment 1	0.61	0.36	-0.25	-41%
commitment 2	0.61	0.36	-0.25	-41%
commitment 3	0.61	0.36	-0.25	-41%
commitment 4	0.61	0.36	-0.25	-41%
commitment 5	0.61	0.37	-0.24	-39%

This table presents the time series average of mpk ($\log(MPK)$) dispersion, under different measures of leased capital after the lease accounting rule change. Compustat item PPENT now includes lease right-of-use asset (ROUANT). Dispersion is defined as the cross-sectional variance. We subtract each mpk from its industry and year mean and work on the residuals. The unadjusted mpk is defined as the log difference between operating income (OIBDP) and owned capital (PPENT - ROUANT), while the adjusted mpk is defined as the log difference between adjusted operating income (OIBDP+XRENT) and the sum of owned capital (PPENT-ROUANT) and leased capital. Each row denotes a commonly used method for estimating leased capital. Leased capital (ASC 842) uses the lease right-of-use asset item (ROUANT) directly reported from Compustat after the lease accounting rule change. For a detailed description of the rest methods, please see Appendix B.2. We report time series averages of the cross section averages in the table. The sample is from 2019 to 2021 and excludes financial, utility, public administrative, and lessor industries from the analysis. Firms that are not incorporated in the US and/or do not report in US dollars are also eliminated.

Figure 1

LAGRANGIAN MULTIPLIER AND LEASED CAPITAL RATIO

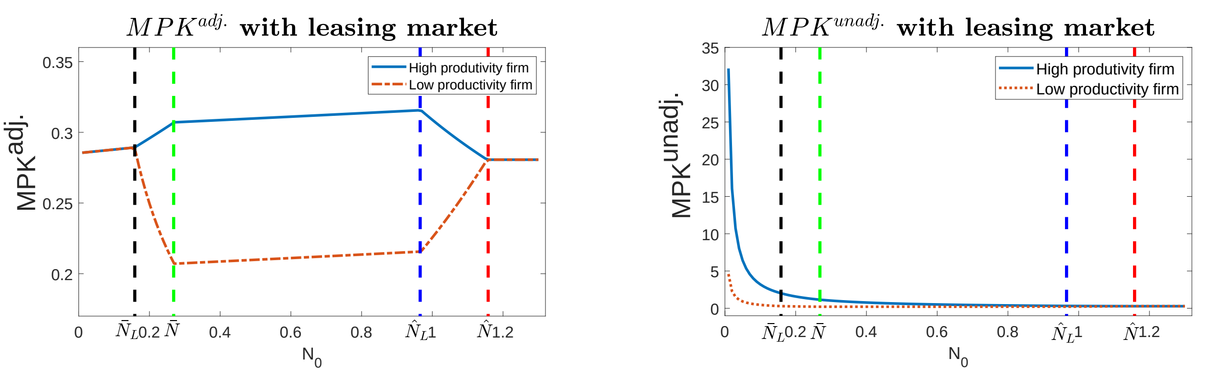


(a) **(b)**

The left panel plots the Lagrangian multiplier of the collateral constraint for high productivity firms (blue) and for low productivity firms (red) as a function of firms' initial wealth. The right panel plots the leased capital ratio for high productivity firms (blue) and for low productivity firms (red) as a function of firms' initial wealth. Parameter values: Discount factor: $\beta = 0.9$; Capital share in production: $\alpha = 0.3$; Depreciation rate: $\delta = 0.1$; Monitoring cost for leased capital due to the separation of ownership and control: $h = 0.1$; Collateralizability in the collateral constraint: $\theta = 0.4$; Firm idiosyncratic productivity and distribution: $z_L = 0.5$, $z_H = 1.32$, $Prob(z_{i1}^T = z_H) = 1 - Prob(z_{i1}^T = z_L) = \pi = 0.5$; and Initial wealth that a representative household is endowed with: $\Omega_0 = 3$.

Figure 2

ADJUSTED AND UNADJUSTED MPK WITH THE RENTAL MARKET

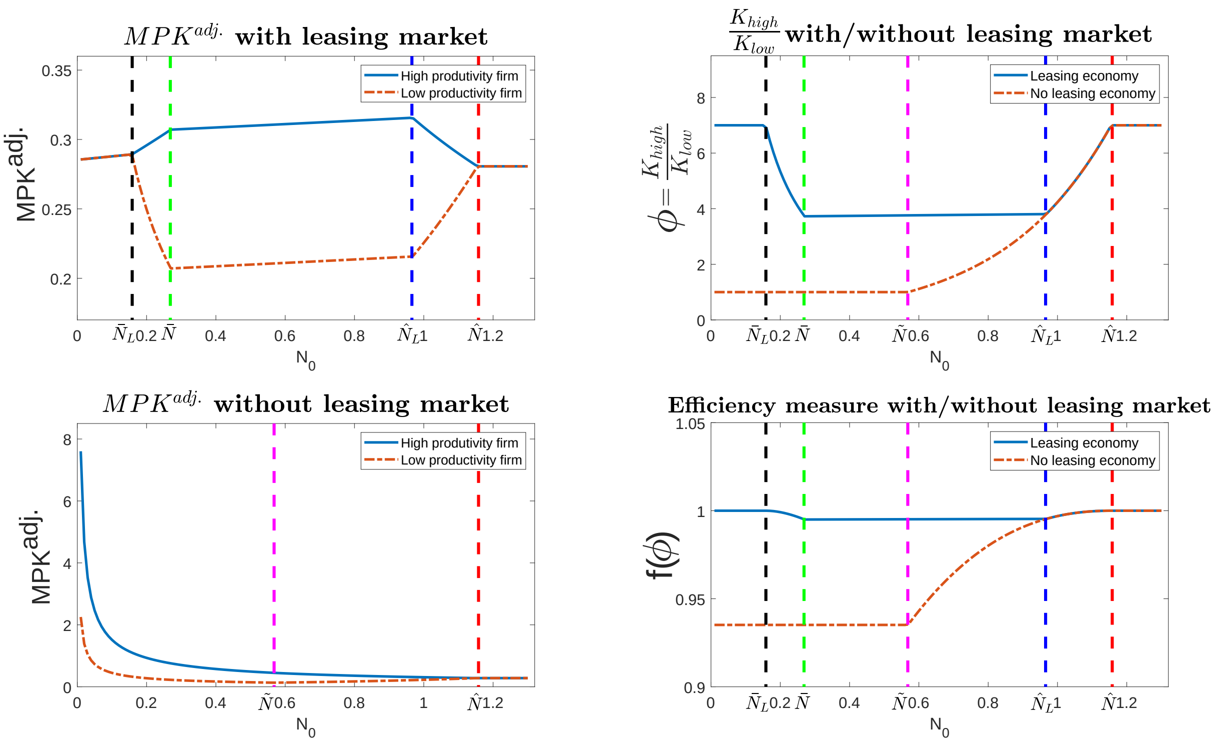


(a) **(b)**

The left panel plots the adjusted MPK for high productivity firms (blue) and for low productivity firms (red) as a function of firms' initial wealth in our model economy. The right panel plots the unadjusted MPK for high productivity firms (blue) and for low productivity firms (red) as a function of firms' initial wealth in our model economy.

Figure 3

COUNTERFACTUAL ANALYSIS WITHOUT THE RENTAL MARKET

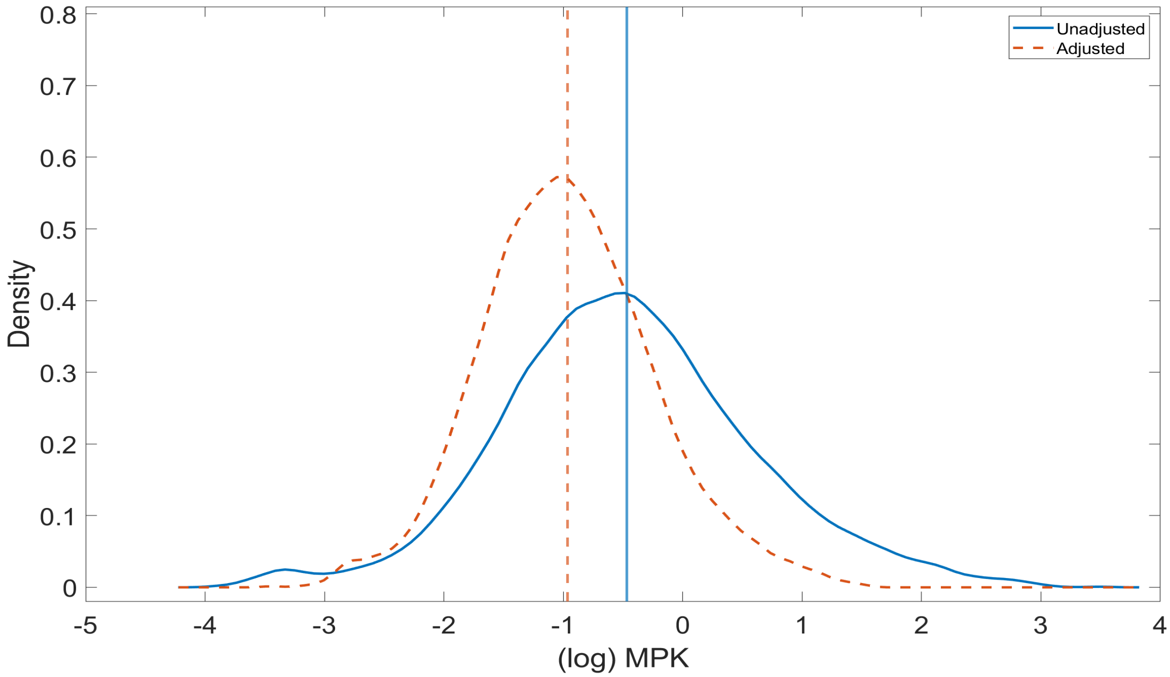


(a) **(b)**

The top left panel plots the adjusted MPK for high productivity firms (blue) and for low productivity firms (red) as a function of firms' initial wealth in our model economy. The bottom left panel plots the adjusted MPK for high productivity firms (blue) and for low productivity firms (red) as a function of firms' initial wealth in the economy where the rental market is artificially shut down. The left right panel plots the ratio of total capital between high productivity and low productivity firms as a function of firms' initial wealth in our model economy (blue) and in the economy where the rental market is artificially shut down (red). The bottom right panel plots the efficiency measure as a function of firms' initial wealth in our model economy (blue) and in the economy where the rental market is artificially shut down (red).

Figure 4

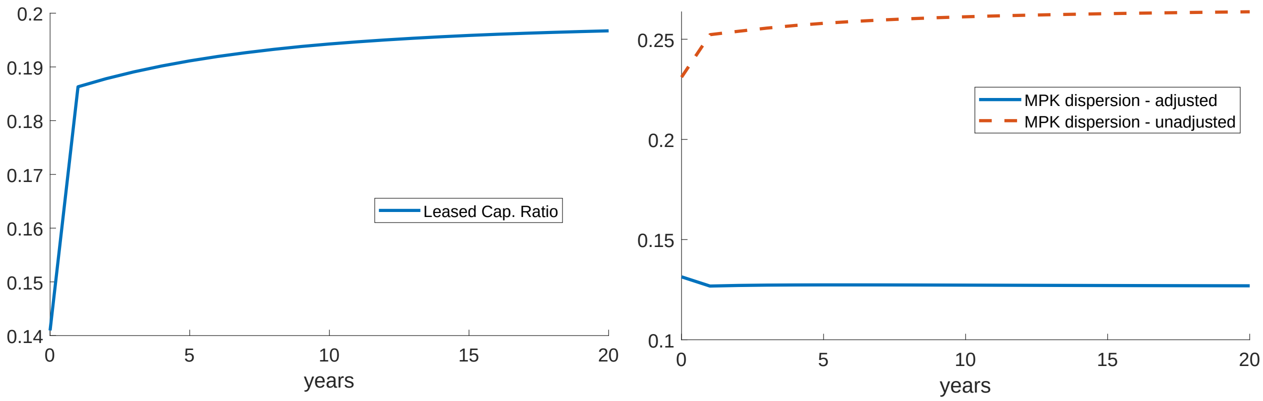
KERNEL PLOT OF LOG MPK FOR BOTH MEASURES



This figure shows the estimated kernel density of $\log(MPK)$. The red line denotes the unadjusted MPK, while the blue line denotes the measure adjusted for leased capital. Vertical lines refer to the means of each distribution.

Figure 5

LEASED CAPITAL RATIO AND MPK DISPERSION DURING TRANSITION

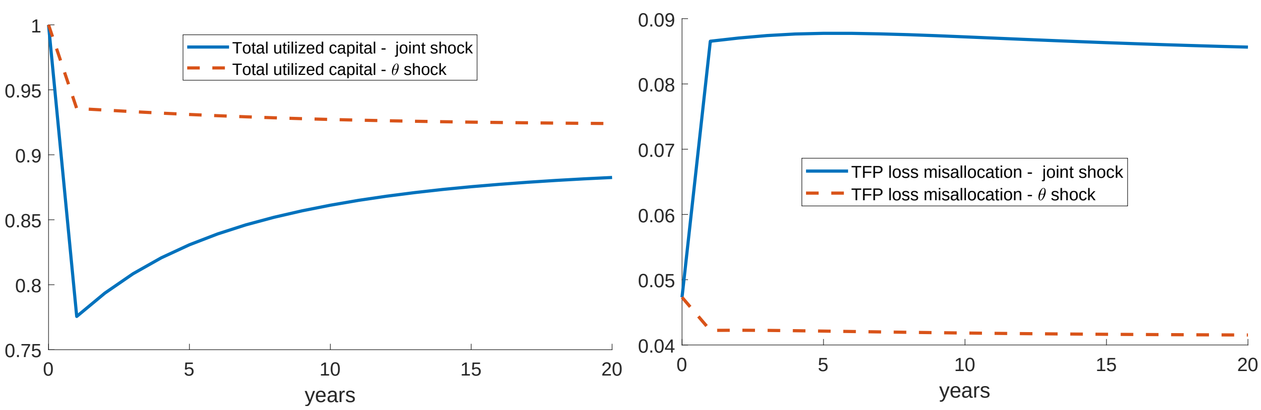


(a) Leased capital ratio **(b)** MPK dispersion

The figure presents the equilibrium transition dynamics associated with an unexpected drop in collateralizability θ. The left panel plots the leased capital ratio, while the right panel plots the unadjusted MPK dispersion (red) and adjusted MPK dispersion (blue).

Figure 6

TRANSITION DYNAMICS COMPARISON

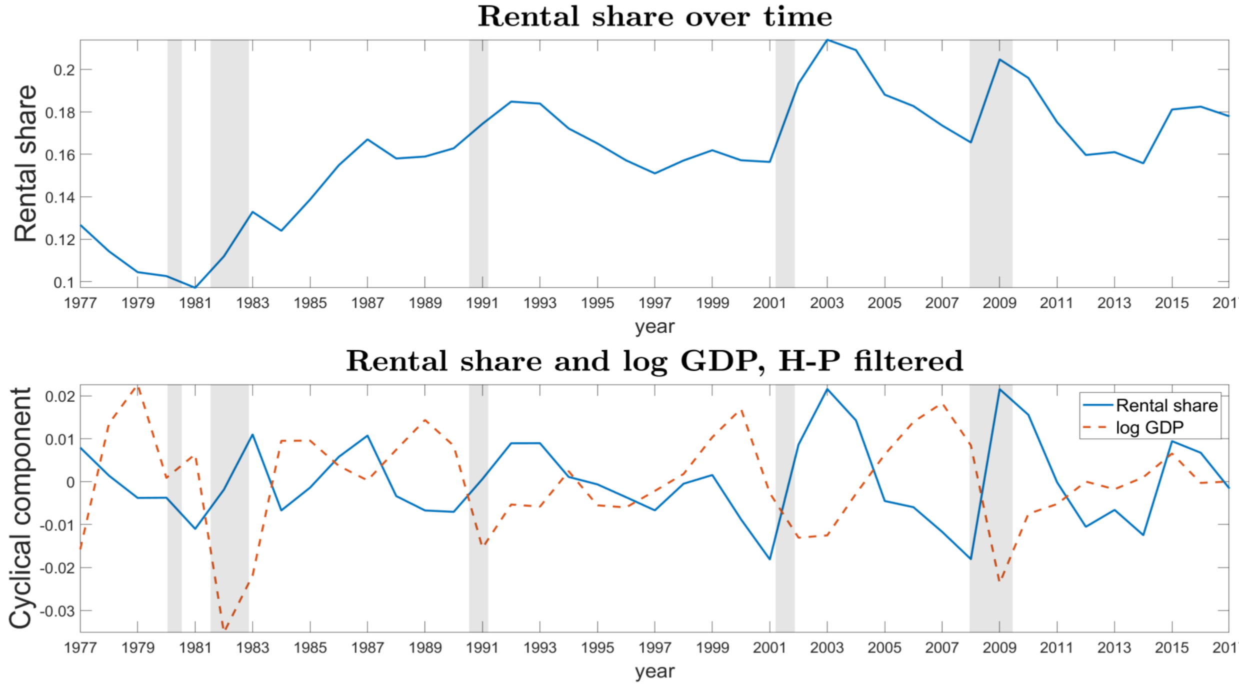


(a) Total utilized capital **(b)** TFP losses

The figure compares the equilibrium transition dynamics associated with 1) an unexpected drop in collateralizability θ (red); and 2) an unexpected drop in collateralizability θ and an increase in monitoring cost h (blue). The left panel plots the total utilized capital under two cases, while the right panel plots the TFP losses under two cases.

Figure 7

OPERATING LEASE OVER THE BUSINESS CYCLE



This figure plots the leased capital ratio (cash-flow based, i.e., rental share) over the business cycle. The top panel plots the leased capital ratio over time. The bottom panel plots the cyclical component of the Hodrick and Prescott (1997) (H-P) filtered ratio and log GDP. The blue line denotes the cyclical component of the ratio. The red line denotes the cyclical component of log GDP. The shaded areas denote NBER business cycle recessions.

Internet Appendix

A Institutional backgrounds of leasing

A.1 History of leasing

The history of leasing can be traced back to around 2000 BC in ancient Sumer. Romans then issued laws on leasing different properties. In 1877, the Bell telephone company first introduced the concept of leasing telephones, rather than selling them, for its telephone services in the US, which has proven critical to its success. However, in the US, the formal arrangements of leasing were not established until the 1950s.

A lease is defined as a "contract, or part of a contract, that conveys the right to control the use of identified property, plant or equipment (an identified asset) for a period of time in exchange for consideration" (FASB, 2016). An operating lease therefore conveys the use of an asset from one party (the lessor) to another (the lessee) without transferring ownership.

We have seen remarkably rapid expansion in leasing markets for recent decades. Several explanations for leasing have been suggested.

Tax Early research on leasing in the finance literature mainly focuses on the tax considerations under the Modigliani–Miller framework (Modigliani and Miller, 1958). In that environment, firms' choice of leasing and buying is largely determined by the different tax treatment of these two options (Miller and Upton, 1976; Myers, Dill, and Bautista, 1976; Lewellen, Long, and McConnell, 1976; Graham, Lemmon, and Schallheim, 1998). The main prediction is that it is more beneficial for low-tax-rate firms to lease, as leasing allows the transfer of tax shields from these firms to those who value tax savings more.[47]

Financial constraints A large and central strand of the literature on leasing focuses

[47] The tax deregulation introduced by "The Economic Recovery Tax Act of 1981" (ERTA) has brought more tax benefits to lessors, which boosted the investment in properties for leasing. The details can be found at https://www.congress.gov/bill/97th-congress/house-bill/4242.

on financial constraints and agency costs associated with the separation of capital ownership and control (Smith Jr and Wakeman, 1985; Sharpe and Nguyen, 1995; Smith Jr and Warner, 1979).[48] Sharpe and Nguyen (1995) provides empirical evidence to support the prediction that more financially constrained firms lease more. Eisfeldt and Rampini (2009) are the first to formally model leasing's greater ability to repossess assets and link it to higher debt capacity, which relaxes financial constraints. Rampini and Viswanathan (2013) study the role of leased capital in a dynamic model of firm financing and risk management. Rampini (2019) extends the financial constraint arguments to asset durability, concluding that more durable assets tend to be leased, as purchasing durable assets has larger financing requirements that are prohibitive for financially constrained firms. Chu (2020) provides a causal analysis on how the ease of repossessing collateral in bankruptcy affects corporate leasing policy.

Other explanations There are also many other explanations for why firms lease. Coase (1972), Bulow (1986), Waldman (1997) and Hendel and Lizzeri (1999) argue that leasing may allow a monopolist to extend market power. Abel and Eberly (1996), Dixit and Pindyck (1994), and Gavazza (2011) explain leasing using flexibility arguments, especially in the face of uncertainty and irreversible capital investments associated with adjustment costs. Graham, Lemmon, and Schallheim (1998) emphasize that, rather than issue debt, firms in financial distress tend to arrange favorable lease agreements. Eisfeldt and Rampini (2009) recognize this point, but suggest that distress considerations may play a secondary role to financial constraints. Hendel and Lizzeri (2002), Johnson and Waldman (2003), Hendel, Lizzeri, and Siniscalchi (2005), and Johnson and Waldman (2010) all suggest the role of leasing in reducing adverse selection. Li and Tsou (2019) argue that leasing allows firms to hedge asset price uncertainty associated with the resale of purchased assets. In addition, the decision of lease versus buy has been studied in the housing literature (Artle and Varaiya, 1978; Stein, 1995; Engelhardt, 1996; Henderson and Ioannides, 1983).

[48] Alchian and Demsetz (1972) recognize the agency problems that leasing involves due to the separation of ownership and control. Smith Jr and Wakeman (1985) provide a discussion of both tax and nontax determinants of the lease versus buy decision.

A.2 Changes in lease accounting rules

In February 2016, the Financial Accounting Standards Board (FASB) issued updated accounting standards for lease (ASU 2016-02, Topic 842). Effective from 2019, firms are required to recognize lease assets and lease liabilities from off-balance-sheet activities on their balance sheets, which increases the transparency and comparability among organizations. Firms must also disclose key information about leasing transactions. The exact adoption rule differs across firms. For public firms and certain other entities, ASC 842 is effective for annual periods beginning after December 15, 2018. For private firms, the new lease accounting adoption was set to be effective for reporting periods beginning subsequent to December 15, 2019.

After adopting the new accounting rule, firms now report "Lease right-of-use asset" on the asset side, and report both short-term and long-term lease liabilities on the liability side. These items were absent before the adoption of the new operating lease accounting rule. Additionally, firms are required to report the estimates of their operating leases, including the value, average regaining life, and discount rate, as well as disclose the possibility of renewing or extending existing leases. Figure A.1 shows the example from Shake Shack's financial statement in 2019. We can see that the new rule has a major impact on both Shake Shack's asset and liability side.

ASC 842 has proved a major change in accounting and FASB has issued several accounting standard updates and amendments to it since the first publishment in 2016. In response to COVID-19, FASB has proposed the deferral of the new lease accounting standard effective date for certain entities such as private entities, including private not-for-profit entities.

In a joint effort, the International Accounting Standards Board (IASB) also released IFRS 16 on new lease standards, requiring nearly all leases to be reported on lessees' balance sheets as assets and liabilities in 2016, effective for annual periods beginning on or after January 1, 2019.

Figure A.1: Financial Statement Example: Shake Shack

SHAKE SHACK INC.
CONSOLIDATED BALANCE SHEETS
(in thousands, except share and per share amounts)

		December 25 2019		December 26 2018
ASSETS				
Current assets:				
Cash and cash equivalents	$	37,099	$	24,750
Marketable securities		36,508		62,113
Accounts receivable		9,970		10,523
Inventories		2,221		1,749
Prepaid expenses and other current assets		1,877		1,984
Total current assets		87,675		101,119
Property and equipment, net		314,862		261,854
Operating lease assets		274,426		—
Deferred income taxes, net		279,817		242,533
Other assets		11,488		5,026
TOTAL ASSETS	$	968,268	$	610,532
LIABILITIES AND STOCKHOLDERS' EQUITY				
Current liabilities:				
Accounts payable	$	14,300	$	12,467
Accrued expenses		24,140		22,799
Accrued wages and related liabilities		11,451		10,652
Operating lease liabilities, current		30,002		—
Other current liabilities		19,499		14,030
Total current liabilities		99,392		59,948

This figure shows excerpts from Shake Shack's balance sheet in its 2019 financial statement. It includes the asset side and the liability side.

Compustat has incorporated the changes to several of its existing data items directly. On the asset side, operating lease-induced assets are directly added to PPENT (Plant, Property, and Equipment - Net), PPEGT (Plant, Property, and Equipment - Gross), and AT (Total Assets). On the liability side, operating lease-induced liabilities are directly added to DLC (Debt in Current Liabilities) and DLTT (Long-Term Debt). To identify these newly available lease items, we can refer to Compustat Snapshot or Compustat table csco-afnd now. For example, the new "ROUANT" item denotes the reported value of operating lease-induced assets, which is directly added to PPENT.[49] We have validated our findings using ROUANT in Appendices 7.3.1 and 7.3.2.

[49] Please see the details of adjustment for financial statements in Yueran Ma's note: https://cpb-us-w2.wpmucdn.com/voices.uchicago.edu/dist/7/1291/files/2017/01/lease.pdf

B Data construction

B.1 Data source

Our sample consists of firms in Compustat, available from WRDS. The sample period ranges from 1977 to 2017. We focus on firms with positive rental expenditure data (XRENT from Compustat), non-missing standard industrial classification (SIC) codes, and firms trading on NYSE, AMEX, and NASDAQ. We exclude utility firms that have four-digit SIC codes between 4900 and 4999, finance firms that have SIC codes between 6000 and 6999 (finance, insurance, trusts, and real estate sectors), as well as public administrative firms that have SIC codes between 9000 and 9999. We also explicitly drop industries that serve as lessors (i.e., SIC code 7377 and industries whose SIC codes begin with 735 and 751). We exclude firm year observations where total assets (AT) are non-positive, or where the book value of common stock (CEQ) or deferred taxes (TXDB) are negative. We additionally eliminate firms that are not incorporated in the US and/or do not report in US dollars. Macroeconomic data are from the Federal Reserve Economic Data (FRED) maintained by the Federal Reserve Bank in St. Louis.

B.2 Constructing leased capital

B.2.1 Leased capital ratio and rental share

We adopt methods in the previous literature to measure leased capital. We define leased capital as eight times current rental payment, following Rampini and Viswanathan (2013) and Lim, Mann, and Mihov (2017). We refer to this direct capitalized item as leased capital (multiplier). This capitalization procedure infers rented capital from rental fees and the user cost of rented capital, in which the user cost is estimated from common figures on interest rate, depreciation rate, and monitoring cost (it implies a user cost of roughly 1/8). This capitalization process is also consistent with the common industry practice.

We omit intangible capital due to the inherent problems with it not being an consistent measure of all intangible investments, valuation, and depreciation. We use Property, Plant, and Equipment - Total (Net), i.e., PPENT, to measure purchased tangible capital and further define leased capital ratio as leased capital divided by the sum of leased and owned capital. Leased capital ratio measures the proportion of total capital input in a firm's production obtained from leasing activity.

The rental share of each firm is defined as the percentage of rental fee accounts for in total expenditure (sum of capital expenditure and rental fee) for each year:

$$\text{Rental share } = \frac{\text{rental expenses}}{\text{rental expenses } + \text{ capital expenditures}}$$

B.2.2 Alternative measures

Below, we discuss other common empirical proxies for the capital amount of operating leases. These measures rely on a discounting method, in which the leased capital is equal to the present value of current and future lease commitments. The difference lies in the numerators as well as the denominators.

Leased capital (commitment 1) The first alternative measure for leased capital follows Li, Whited, and Wu (2016). We discount future lease commitments in years 1-5 (MRC1–MRC5) at the BAA bond rate. We similarly discount lease commitments beyond year 5 (MRCTA) by assuming that they are evenly spread out in years six to ten. The leased capital, then, is the sum of current rental payment and the present value of future lease commitments as calculated above, which we denote as leased capital (commitment 1).

Leased capital (commitment 2) For leased capital (commitment 2), we define everything similarly as leased capital (commitment 1), except for the treatment of MRCTA. Instead of assuming that lease commitments beyond year 5 (MRCTA) are evenly spread out in years six to ten, we follow Rauh and Sufi (2012) to include the estimated value of the rental commitments due beyond year 5. We first divide MRCTA by the average lease commitments over the first five years, and obtain an estimate of the remaining life of a firm's operating leases after year 5. Then we spread MRCTA evenly over the approximate remaining life of the leases. Eventually, we discount these estimated lease commitments beyond year 5 by the BAA bond rate.

Leased capital (commitment 3) We define everything similarly as leased capital (commitment 1), except for the treatment of MRCTA. Since lease commitments beyond year 5 (MRCTA) in Compustat are often missing, especially in earlier years (prior to 2000), we do not include the present value of MRCTA, as in Chu (2020) and Graham, Lemmon, and Schallheim (1998). We denote this measure as leased capital (commitment 3).

Leased capital (commitment 4) We define everything similarly as leased capital (commitment 1), except for the discount rate. Here we set the discount rate to a constant value of 10% for all firms, in order to determine the present values. This is in line with Graham, Lemmon, and Schallheim (1998) and Cornaggia, Franzen, and Simin (2013). We denote this measure as leased capital (commitment 4).

Leased capital (commitment 5) We define everything similarly as leased capital (commitment 5), except for the discount rate. Alternatively, we follow Graham and Lin (2018) and employ a firm-specific discount rate. We calculate the firm-specific discount rate as the ratio of a firm's interest expense (XINT) divided by the sum of short-term and long-term debt (DLC and DLTT, respectively) if possible. If a firm's interest expense is zero or missing, we set it to be the median value of that within the same two-digit SIC code industry. We denote this measure as leased capital (commitment 5).

Table B.1 provides a summary of these measures.

Table B.1

REFERENCES FOR LEASED CAPITAL MEASURES ACROSS DIFFERENT METHODOLOGIES

Leased capital	References
multiplier	Rampini and Viswanathan (2013) and Rampini and Viswanathan (2020)
commitment 1	Li, Whited, and Wu (2016)
commitment 2	Rauh and Sufi (2012)
commitment 3	Chu (2020) and Graham, Lemmon, and Schallheim (1998)
commitment 4	Graham, Lemmon, and Schallheim (1998) and Cornaggia, Franzen, and Simin (2013)
commitment 5	Graham and Lin (2018)

This table presents the references for different methods used to compute the estimates of leased capital.

C Derivations for the two-period model

C.1 Setup for the two-period model

Here we describe our two-period model in detail. In the two-period case, we keep all else the same as in our dynamic model, except that there are several additional simplifying assumptions and that the world ends in two periods.

C.1.1 Household

The household is endowed with an initial wealth Ω_0 and maximizes log utility subject to standard intertemporal budget constraints:

$$\max_{C_0^H, C_1^H, B_0, K^l} E\left[\sum_{t=0}^{1} \beta^t u\left(C_t^H\right)\right], \tag{C1}$$

$$s.t.: C_0^H + B_0 + K_1^l = \Omega_0, \tag{C2}$$

$$\tau_l K_1^l + (1-\delta-h)K_1^l + R_f B_0 + W = C_1^H, \tag{C3}$$

where β is the discount factor, and C_0^H and C_1^H denote the household's consumption at period 0 and period 1, respectively. At period 0, the household i) preserves B_0 amount of cash for purchasing risk-free bonds, which yield gross risk-free interest rate R_f at period 1; and ii) transforms net worth into K_1^l amount of leased capital to get the leasing payment $\tau_l K_1^l$ as well as the resale value of leased capital $(1-\delta-h)K_1^l$ at period 1. δ is the rate of capital depreciation, and h is the monitoring cost of leased capital due to the separation of ownership and control, as in Eisfeldt and Rampini (2009) and Rampini and Viswanathan (2013). Since labor supply is inelastic and normalized to one, the household also receives the labor income W at period 1.

Under log utility, we have $E\left[\beta \frac{C_0^H}{C_1^H} R_f\right] = 1$. The first-order condition of K_1^l indicates that $\tau_l + 1 - \delta - h = R_f$.

C.1.2 Nonfinancial firms

There are two types of nonfinancial firms in our model: final goods producers and intermediate goods producers. Since a final goods producer does not make intertemporal decisions, its problem in the two-period model is identical to that in our dynamic model, except that it only has two periods.

Intermediate goods producers There is a unit measure of competitive intermediate goods producers, $i \in [0,1]$, each of which produces a different variety of goods. We assume that firm i is endowed with the same initial wealth N_0.

Each firm faces a Cobb-Douglas production technology:

$$y_i = z_{i1}^T \left((K_{i1}^o + K_{i1}^l) \right)^\alpha L_i^{1-\alpha}. \tag{C4}$$

We specify the maximization problem for each firm i as:

$$\max_{C_{it}, B_{i0}, K_{i1}^{l}, K_{i1}^{o}, L_i} E\left[C_{i0} + R_f^{-1} C_{i1}\right], \tag{C5}$$

$$C_{i0} + K_{i1}^{o} = N_0 + B_{i0}, \tag{C6}$$

$$C_{i1} = p_i y_i - \tau_l K_{i1}^{l} - R_f B_{i0} + (1-\delta) K_{i1}^{o} - W L_i, \tag{C7}$$

$$B_{i0} \leq \theta K_{i1}^{o}, \tag{C8}$$

$$K_{i1}^{o} \geq 0, \tag{C9}$$

$$K_{i1}^{l} \geq 0, \tag{C10}$$

$$C_{it} \geq 0, \quad (t = 0, 1) \tag{C11}$$

where $i = H, L$. τ_l is the equilibrium leasing fee for each unit of leased capital. At the end of period 0, firm i issues bond B_{i0}, buys owned capital K_{i1}^{o}, and discusses with the household for leased capital K_{i1}^{l}. The key constraint for borrowing is $B_{i0} \leq \theta K_{i1}^{o}$. In the morning of period 1, the idiosyncratic productivity shock is realized. Firm i uses the owned capital and pre-agreed leased capital to produce. The capital amount used for production does not suffer depreciation because the time interval is so short. After production, both types of capital suffer depreciation. Firm i has to pay back bond, interest, and leasing fees. It resells owned capital and gives back the depreciated leased capital to the household.

C.1.3 Market clearing conditions

To complete the specification of the model, we list the market clearing conditions as follows:

$$C_0^H + \int C_{i0} di + \int K_{i1}^o di + K_1^l = \Omega_0 + \int N_0 di, \tag{C12}$$

$$Y + \int (1-\delta) K_{i1}^o di + (1-\delta-h) K_1^l = C_1^H, \tag{C13}$$

$$B_0 = \int B_{i0} di, \tag{C14}$$

$$K_1^l = \int K_{i1}^l di, \tag{C15}$$

$$\int L_i di = 1. \tag{C16}$$

The first two equations are the market clearing conditions for final output at period 0 and period 1, respectively. Eq. (C14) corresponds to the bond market clearing condition. Eq. (C15) is the leased capital market clearing condition. The last equation represents the labor market clearing condition, where we have normalized the total labor supply to one.

C.2 Lagrangian for the two-period model

Without loss of generality, we assume that firms only consume at period 1, i.e., $C_{i0} = 0$. To facilitate discussion, we present the Lagrangian of firm i with our simplifying assumptions:

$$
\begin{aligned}
\mathcal{L}_i \quad = \quad & \max R_f^{-1} C_{i1} \\
& + \eta_{i0} \left[\ N_0 + B_{i0}^i - K_{i1}^o \ \right] \\
+ \quad \eta_{i1} \quad & \left[\ p_i y_i - \tau_l K_{i1}^l - R_f B_{i0} - C_{i1} + (1-\delta) K_{i1}^o - W L_i \ \right] \\
& + \xi_{i0} \eta_{i0} \left[\theta K_{i1}^o - B_{i0} \right] \\
& + \bar{\nu}_{i0} \eta_{i0} K_{i1}^o \\
& + \underline{\nu}_{i0} \eta_{i0} K_{i1}^l \\
& + d_{i1} C_{i1}.
\end{aligned}
$$

F.O.C.s:

$$[C_{i1}] : R_f^{-1} - \eta_{i1} + d_{i1} = 0, \tag{C17}$$

$$[K_{i1}^o] : -\eta_{i0} + \left[\frac{\alpha p_i y_i}{K_{i1}^o + K_{i1}^l} + (1-\delta) \right] \eta_{i1} + \theta \xi_{i0} \eta_{i0} + \bar{\nu}_{i0} \eta_{i0} = 0, \tag{C18}$$

$$[K_{i1}^l] : \alpha \frac{p_i y_i}{K_{i1}^o + K_{i1}^l} \eta_{i1} - \tau_l \eta_{i1} + \underline{\nu}_{i0} \eta_{i0} = 0, \tag{C19}$$

$$[B_{i0}] : \eta_{i0} - R_f \eta_{i1} - \xi_{i0} \eta_{i0} = 0, \tag{C20}$$

$$[L_i] : (1-\alpha) \frac{p_i y_i}{L_i} = W, \tag{C21}$$

where d_{i1} must be zero, since C_{1i} is sure to be positive. In our setup, firms must always have owned capital; hence, $\bar{\nu}_{i0}$ must be 0.

C.3 Propositions for the two-period model

Let K_i denote the total amount of capital used by a firm. Using the fact that $y_i = {p_i}^{-\eta} Y$, we can write:

$$p_i y_i = y_i^{1-\frac{1}{\eta}} Y^{\frac{1}{\eta}} = \left[z_{i1}^T K_i^{\alpha} L_i^{1-\alpha}\right]^{1-\frac{1}{\eta}} Y^{\frac{1}{\eta}}, \tag{C22}$$

Because firms are perfectly competitive, their decisions on capital don't affect their prices. The price is an equilibrium concept. Hence, we can write the (true) marginal product of capital as:

$$MPK_i = MPK_i^{(T)} = \alpha \left(z_{i1}^T\right)^{1-\frac{1}{\eta}} K_i^{\alpha\left(1-\frac{1}{\eta}\right)-1} L_i^{(1-\alpha)\left(1-\frac{1}{\eta}\right)} Y^{\frac{1}{\eta}}, \tag{C23}$$

and write the marginal product of labor as:

$$W = (1-\alpha) \left(z_{i1}^T\right)^{1-\frac{1}{\eta}} K_i^{\alpha\left(1-\frac{1}{\eta}\right)} L_i^{(1-\alpha)\left(1-\frac{1}{\eta}\right)-1} Y^{\frac{1}{\eta}}. \tag{C24}$$

This equation implies $L_i \propto \left[z_{i1}^T K_i^{\alpha}\right]^{\frac{1-\frac{1}{\eta}}{1-(1-\alpha)\left(1-\frac{1}{\eta}\right)}}$. Using the resource constraint, $\int L_i di = 1$, we can obtain:

$$L_i = \frac{\left[z_{i1}^T K_i^{\alpha}\right]^{\frac{1-\frac{1}{\eta}}{1-(1-\alpha)\left(1-\frac{1}{\eta}\right)}}}{\int \left[\left[z_{i1}^T K_i^{\alpha}\right]^{\frac{1-\frac{1}{\eta}}{1-(1-\alpha)\left(1-\frac{1}{\eta}\right)}}\right] di}. \tag{C25}$$

We denote $\triangledown = \int \left[\left[z_{i1}^T K_i^{\alpha}\right]^{\frac{1-\frac{1}{\eta}}{1-(1-\alpha)\left(1-\frac{1}{\eta}\right)}}\right] di$. Then we can write:

$$\begin{aligned} MPK_i^{(T)} &= \alpha \frac{p_i y_i}{K_i} \\ &= \alpha \left(z_{i1}^T\right)^{\frac{\eta-1}{1+\alpha\eta-\alpha}} K_i^{\frac{-1}{1+\alpha\eta-\alpha}} \triangledown^{\frac{\alpha\eta-\alpha+1}{(\eta-1)}-1}. \end{aligned} \tag{C26}$$

Under the two period model, we define $\frac{K_H}{K_L} = \phi$. Then the optimal $\hat{\phi} = \left(\frac{z_H}{z_L}\right)^{\eta-1}$.

Now,

$$\begin{aligned} \bigtriangledown &= \int \left[\left[z_{i1}^{T} K_{i}^{\alpha} \right]^{\frac{1-\frac{1}{\eta}}{1-(1-\alpha)\left(1-\frac{1}{\eta}\right)}} \right] di \\ &= \pi \left[z_{H} K_{H}^{\alpha} \right]^{\frac{1-\frac{1}{\eta}}{1-(1-\alpha)\left(1-\frac{1}{\eta}\right)}} + (1-\pi) \left[z_{L} K_{L}^{\alpha} \right]^{\frac{1-\frac{1}{\eta}}{1-(1-\alpha)\left(1-\frac{1}{\eta}\right)}} . \end{aligned}$$

C.3.1 Proposition 1

To prove Proposition 1, we start with the case in which no firms are constrained. In this case, both types of firms choose optimally, and the economy achieves the first best outcome. Both types of firms have an equalized MPK, $R_{f,u} - 1 + \delta$.

We denote the capital requirement for high productivity and low productivity firms as $\widehat{K}_H$ and $\widehat{K}_L$, respectively. In this first best case, we have:

$$\alpha \left(z_H \right)^{\frac{\eta-1}{1+\alpha\eta-\alpha}} \left(\widehat{K}_H \right)^{\frac{-1}{1+\alpha\eta-\alpha}} \left\{ \int \left[\left[z_{i1}^{T} \left(\widehat{K}_i \right)^{\alpha} \right]^{\frac{\eta-1}{\alpha\eta-\alpha+1}} \right] di \right\}^{\frac{\alpha\eta-\alpha+1}{(\eta-1)}-1} = R_{f,u} - 1 + \delta,$$

$$\alpha \left(z_L \right)^{\frac{\eta-1}{1+\alpha\eta-\alpha}} \left(\widehat{K}_L \right)^{\frac{-1}{1+\alpha\eta-\alpha}} \left\{ \int \left[\left[z_{i1}^{T} \left(\widehat{K}_i \right)^{\alpha} \right]^{\frac{\eta-1}{\alpha\eta-\alpha+1}} \right] di \right\}^{\frac{\alpha\eta-\alpha+1}{(\eta-1)}-1} = R_{f,u} - 1 + \delta.$$

It is obvious that $\widehat{K}_H > \widehat{K}_L$. As firms' initial wealth N_0 drops, eventually they cannot optimally choose the desired capital level. Intuitively, high productivity firms will become constrained first since they require higher optimal capital. Therefore, they require higher initial wealth.

To prove this, we start from a slightly different angle and assume that firms are not endowed with the same initial wealth N_0. Suppose that at initial wealth $\widehat{N}_H$, high productivity firms just become constrained. Similarly, at initial wealth $\widehat{N}_L$, low productivity firms just become constrained. Meanwhile, suppose both types of firms just become constrained at the same time in the same economy. We denote $\lambda = \frac{1}{1-\theta}$. Therefore,

$$\alpha \left(z_H\right)^{\frac{\eta-1}{1+\alpha\eta-\alpha}} \left(\lambda \widehat{N}_H\right)^{\frac{-1}{1+\alpha\eta-\alpha}} \left\{\int \left[\left[z_{i1}^T \left(\widehat{K}_i\right)^{\alpha}\right]^{\frac{\eta-1}{\alpha\eta-\alpha+1}}\right] di\right\}^{\frac{\alpha\eta-\alpha+1}{(\eta-1)}-1} = R_{f,c} - 1 + \delta,$$

$$\alpha \left(z_L\right)^{\frac{\eta-1}{1+\alpha\eta-\alpha}} \left(\lambda \widehat{N}_L\right)^{\frac{-1}{1+\alpha\eta-\alpha}} \left\{\int \left[\left[z_{i1}^T \left(\widehat{K}_i\right)^{\alpha}\right]^{\frac{\eta-1}{\alpha\eta-\alpha+1}}\right] di\right\}^{\frac{\alpha\eta-\alpha+1}{(\eta-1)}-1} = R_{f,c} - 1 + \delta.$$

It implies that:

$$\widehat{N}_H > \widehat{N}_L,$$

which means that, in the same economy, high productivity firms would require higher net worth to begin with, so that they just switch from being unconstrained to being constrained. Low productivity firms would require lower initial net worth.

We now revert back to the original case in which firms are given the same N_0. Following the above logic, we can clearly see that when N_0 decreases, high productivity firms naturally become constrained earlier than low productivity firms.

We denote this threshold as $\widehat{N}$. When $N_0 > \widehat{N}$, both types of firms are unconstrained. When $N_0 \leq \widehat{N}$, high productivity firms will be constrained while low productivity firms are still unconstrained.

As the initial wealth N_0 further drops, both types of firms will become constrained. We denote this threshold as $\overline{N}$.

C.3.2 Proposition 2

We denote the threshold that high productivity firms start to use leased capital as $\widehat{N}_L$, and the threshold that low productivity firms start to use leased capital as $\overline{N}_L$.

When firms use leased capital, their MPK is equal to the sum of the net interest rate, depreciation rate, and monitoring cost. Following similar logic in the proof for Proposition 1, we know that high productivity firms will start to use leased capital earlier than low productivity firms. This is because high productivity firms always require higher initial wealth, and thus they will become sufficiently constrained to use leased capital earlier than low productivity firms, when both types are given the same initial wealth. Consequently, $\widehat{N}_L > \overline{N}_L$.

From the user cost comparison in subsection 3.2.2, we know that only when firms become sufficiently constrained will they begin to lease. Hence, $\widehat{N} > \widehat{N}_L$ and $\overline{N} > \overline{N}_L$.

We next compare $\widehat{N}_L$ and $\overline{N}$. We again use the logic in the proof for Proposition 1. Suppose that firms' initial wealth are not the same. Meanwhile, we focus on the case in which high productivity firms just begin to lease capital and low productivity firms just become constrained. In this scenario, we denote the initial wealth requirement for high productivity firms as $\widehat{n}_L$, and denote the initial wealth requirement for low productivity firms as $\overline{n}$.

From our MPK formulas, we know:

$$\widehat{n}_L = \frac{1}{\lambda}\left(\frac{R_{f,lc} - 1 + \delta + h}{\alpha\left(z_H\right)^{\frac{\eta-1}{1+\alpha\eta-\alpha}}\left\{\int\left[\left[z_{i1}^T\left(\widehat{K}_i\right)^{\alpha}\right]^{\frac{\eta-1}{\alpha\eta-\alpha+1}}\right]di\right\}^{\frac{\alpha\eta-\alpha+1}{(\eta-1)}-1}}\right)^{\alpha-1-\alpha\eta},$$

$$\overline{n} = \frac{1}{\lambda}\left(\frac{R_{f,lc} - 1 + \delta}{\alpha\left(z_L\right)^{\frac{\eta-1}{1+\alpha\eta-\alpha}}\left\{\int\left[\left[z_{i1}^T\left(\widehat{K}_i\right)^{\alpha}\right]^{\frac{\eta-1}{\alpha\eta-\alpha+1}}\right]di\right\}^{\frac{\alpha\eta-\alpha+1}{(\eta-1)}-1}}\right)^{\alpha-1-\alpha\eta}.$$

The comparison between $\widehat{n}_L$ and $\overline{n}$ can be reduced to:

$$\frac{R_{f,lc} - 1 + \delta + h}{\alpha\left(z_H\right)^{\frac{\eta-1}{1+\alpha\eta-\alpha}}} \text{ versus } \frac{\left(R_{f,lc} - 1 + \delta\right)\left(\frac{z_H}{z_L}\right)^{\frac{\eta-1}{1+\alpha\eta-\alpha}}}{\alpha\left(z_H\right)^{\frac{\eta-1}{1+\alpha\eta-\alpha}}},$$

and hence,

$$h \text{ versus } \left(R_{f,lc} - 1 + \delta\right)\left(\left(\frac{z_H}{z_L}\right)^{\frac{\eta-1}{1+\alpha\eta-\alpha}} - 1\right).$$

Based on our benchmark parameters (and calculated R_f), the former is smaller than the latter one. This suggests that only when high productivity firms are endowed with higher initial wealth will they lease capital at the same time when low productivity firms become constrained - i.e., $\widehat{n}_L > \overline{n}$.

Following this logic, we revert back to our original scenario in which firms are given the same N_0. We can conclude that, as N_0 drops, high productivity firms will begin leasing earlier than when low productivity firms become constrained. Therefore, $\widehat{N}_L > \overline{N}$.

C.3.3 Proposition 3

From FOCs in Lagrangian, we know $\frac{MPK_i^{(T)}}{W} = \frac{\alpha}{1-\alpha}\frac{L_i}{K_i}$. Therefore, for any individual, the total capital versus labor ratio is:

$$\frac{L_i}{K_i} = \frac{(1-\alpha)\,MPK_i^{(T)}}{\alpha W}. \tag{C27}$$

We can then write L_i and K_i in terms of y_i using $y_i = z_{i1}^T K_i^{\alpha} L_i^{1-\alpha}$:

$$K_i = \frac{y_i}{z_{i1}^T}\left(\frac{\alpha W}{(1-\alpha)\,MPK_i^{(T)}}\right)^{1-\alpha}, \tag{C28}$$

$$L_i = \frac{y_i}{z_{i1}^T}\left(\frac{\alpha W}{(1-\alpha)\,MPK_i^{(T)}}\right)^{-\alpha}. \tag{C29}$$

Using the demand function $y_i = p_i^{-\eta} Y$, we do an integration:

$$K-total = Y\int \frac{p_i^{-\eta}}{z_{i1}^T}\left(\frac{\alpha W}{(1-\alpha)\,MPK_i^{(T)}}\right)^{1-\alpha} di, \tag{C30}$$

$$L-total = Y\int \frac{p_i^{-\eta}}{z_{i1}^T}\left(\frac{\alpha W}{(1-\alpha)\,MPK_i^{(T)}}\right)^{-\alpha} di. \tag{C31}$$

Consequently,

$$\left(K-total\right)^{\alpha}\left(L-total\right)^{1-\alpha}=Y\left\{\int\frac{p_i^{-\eta}}{z_{i1}^T}\left(\frac{1}{MPK_i^{(T)}}\right)^{1-\alpha}di\right\}^{\alpha}\left\{\int\frac{p_i^{-\eta}}{z_{i1}^T}\left(\frac{1}{MPK_i^{(T)}}\right)^{-\alpha}di\right\}^{1-\alpha}. \tag{C32}$$

This implies that TFP is:

$$TFP=\frac{1}{\left\{\int\frac{p_i^{-\eta}}{z_{i1}^T}\left(\frac{1}{MPK_i^{(T)}}\right)^{1-\alpha}di\right\}^{\alpha}\left\{\int\frac{p_i^{-\eta}}{z_{i1}^T}\left(\frac{1}{MPK_i^{(T)}}\right)^{-\alpha}di\right\}^{1-\alpha}}. \tag{C33}$$

From now on, we simplify p_i. From the FOCs, we know:

$$\begin{cases}MPK_i^{(T)}K_i & =\alpha p_i y_i,\\ \\ WL_i & =\left(1-\alpha\right)p_i y_i.\end{cases}$$

Thus,

$$p_i y_i = MPK_i^{(T)}K_i + WL_i. \tag{C34}$$

Also,

$$MPK_i^{(T)}K_i + WL_i = \frac{y_i}{z_{i1}^T}\left(\frac{MPK_i^{(T)}}{\alpha}\right)^{\alpha}\left(\frac{W}{1-\alpha}\right)^{1-\alpha}. \tag{C35}$$

As a result,

$$p_i=\frac{1}{z_{i1}^T}\left(\frac{MPK_i^{(T)}}{\alpha}\right)^{\alpha}\left(\frac{W}{1-\alpha}\right)^{1-\alpha}. \tag{C36}$$

Since the price of the final good is 1, we have (from the zero profit condition for final good producer) $1=P=\left[\int_{[0,1]}p_i^{1-\eta}di\right]^{\frac{1}{1-\eta}}$. Motivated by this, we do another integration, which is:

$$1=\left[\int_{[0,1]}\left\{\frac{1}{z_{i1}^{T}}\left(\frac{MPK_i^{(T)}}{\alpha}\right)^{\alpha}\left(\frac{W}{1-\alpha}\right)^{1-\alpha}\right\}^{1-\eta}di\right]^{\frac{1}{1-\eta}}, \tag{C37}$$

and we can obtain:

$$\left(\frac{W}{1-\alpha}\right)^{(1-\alpha)}=\left[\int_{[0,1]}\left\{\frac{1}{z_{i1}^{T}}\left(\frac{MPK_i^{(T)}}{\alpha}\right)^{\alpha}\right\}^{1-\eta}di\right]^{-\frac{1}{1-\eta}}. \tag{C38}$$

We then have (from Eq. (C36)):

$$p_i=\frac{\frac{1}{z_{i1}^{T}}\left(\frac{MPK_i^{(T)}}{\alpha}\right)^{\alpha}}{\left[\int_{[0,1]}\left\{\frac{1}{z_{i1}^{T}}\left(\frac{MPK_i^{(T)}}{\alpha}\right)^{\alpha}\right\}^{1-\eta}di\right]^{\frac{1}{1-\eta}}}. \tag{C39}$$

Therefore, combined with Eq. (C33), we can write TFP as:

$$TFP=\frac{\left[\int_{[0,1]}\left(\frac{1}{z_{i1}^{T}}\right)^{1-\eta}\left(MPK_i^{(T)}\right)^{\alpha-\alpha\eta}di\right]^{\frac{1+\alpha\eta-\alpha}{\eta-1}}}{\left\{\int\left(\frac{1}{z_{i1}^{T}}\right)^{1-\eta}\left(MPK_i^{(T)}\right)^{\alpha-1-\alpha\eta}di\right\}^{\alpha}}, \tag{C40}$$

and this TFP is $f(\phi)$ in Proposition 3.

Finally, we apply Eq. (C26) and get:

$$f(\phi) \;=\; \frac{\left\{\int\left\{\left[z_{i1}^{T}K_i^{\alpha}\right]^{\frac{\eta-1}{1+\alpha\eta-\alpha}}\right\}di\right\}^{\frac{1+\alpha\eta-\alpha}{\eta-1}}}{\left\{\int K_i di\right\}^{\alpha}}. \tag{C41}$$

Under the two period model, since we have already defined $\frac{K_H}{K_L} = \phi$ and the optimal $\hat{\phi} = \left(\frac{z_H}{z_L}\right)^{\eta-1}$. Then

$$\begin{aligned}
MPK_i^{(T)} &= \alpha\left(z_{i1}^T\right)^{\frac{\eta-1}{1+\alpha\eta-\alpha}}\left(K_i\right)^{\frac{-1}{1+\alpha\eta-\alpha}}\bigtriangledown^{\frac{\alpha\eta-\alpha+1}{(\eta-1)}-1} \\
&= \alpha\left(z_{i1}^T\right)^{\frac{\eta-1}{1+\alpha\eta-\alpha}}\left(K_i\right)^{\frac{-1}{1+\alpha\eta-\alpha}} \\
&* \left\{(1-\pi)\left[z_L K_L^\alpha\right]^{\frac{1-\frac{1}{\eta}}{1-(1-\alpha)\left(1-\frac{1}{\eta}\right)}} + \pi\left[z_H K_H^\alpha\right]^{\frac{1-\frac{1}{\eta}}{1-(1-\alpha)\left(1-\frac{1}{\eta}\right)}}\right\}^{\frac{\alpha\eta-\alpha+1}{(\eta-1)}-1}, \\
\Rightarrow MPK_i^{(T)} &= \alpha\left(z_{i1}^T\right)^{\frac{\eta-1}{1+\alpha\eta-\alpha}}\left(K_i\right)^{\frac{-1}{1+\alpha\eta-\alpha}}\left\{(1-\pi)+\pi\left[\phi^\alpha\left(\hat{\phi}\right)^{\frac{1}{\eta-1}}\right]^{\frac{\eta-1}{1+\alpha\eta-\alpha}}\right\}^{\frac{\alpha\eta-\alpha+1}{(\eta-1)}-1} \\
&* \left[z_L K_L^\alpha\right]^{\left(1-\frac{\eta-1}{1+\alpha\eta-\alpha}\right)}.
\end{aligned}$$

From Eq. (C41):

$$\begin{aligned}
f(\phi) = TFP &= \frac{\left\{\int\left\{\left[z_{i1}^T K_i^\alpha\right]^{\frac{\eta-1}{1+\alpha\eta-\alpha}}\right\}di\right\}^{\frac{1+\alpha\eta-\alpha}{\eta-1}}}{\left\{\int K_i di\right\}^\alpha} \\
&= \frac{\left\{(1-\pi)\left[z_L K_L^\alpha\right]^{\frac{\eta-1}{1+\alpha\eta-\alpha}} + \pi\left[z_H K_H^\alpha\right]^{\frac{\eta-1}{1+\alpha\eta-\alpha}}\right\}^{\frac{\alpha\eta-\alpha+1}{(\eta-1)}}}{\left[(1-\pi)K_L + \pi K_H\right]^\alpha} \\
&= \left\{(1-\pi)\left(\frac{z_L}{\left((1-\pi)+\pi\phi\right)^\alpha}\right)^{\frac{(\eta-1)}{\alpha\eta-\alpha+1}} + \pi\left(\frac{z_H\phi^\alpha}{\left((1-\pi)+\pi\phi\right)^\alpha}\right)^{\frac{(\eta-1)}{\alpha\eta-\alpha+1}}\right\}^{\frac{\alpha\eta-\alpha+1}{(\eta-1)}},
\end{aligned}$$

Under the normalization of two types of shocks:

$$(1-\pi)z_L^{\eta-1} + \pi z_H^{\eta-1} = 1.$$

We have:

$$(1-\pi)z_L^{\eta-1} + \pi\left(\hat{\phi}z_L^{\eta-1}\right) = 1.$$

Thus:

$$\begin{cases}
z_L &= \left(\frac{1}{\pi\hat{\phi}+(1-\pi)}\right)^{\frac{1}{\eta-1}}, \\
z_H &= \left(\frac{\hat{\phi}}{\pi\hat{\phi}+(1-\pi)}\right)^{\frac{1}{\eta-1}}.
\end{cases}$$

Hence, we replace z_L and use $K = \pi K_H + (1-\pi)K_L$, and we obtain:

$$\begin{aligned} MPK_L^{(T)} &= \alpha \left(\frac{1}{\pi\hat{\phi} + (1-\pi)} \right)^{\frac{1}{\eta-1}} K^{\alpha-1} \left[(1-\pi) + \pi\phi \right] \left[(1-\pi) + \pi\hat{\phi} \right]^{\frac{1}{\eta-1}} \\ &\quad * \left\{ (1-\pi) + \pi\hat{\phi}^{\frac{1}{\alpha\eta-\alpha+1}} \phi^{\frac{\alpha(\eta-1)}{\alpha\eta-\alpha+1}} \right\}^{-1} f(\phi), \end{aligned}$$

$$\Rightarrow MPK_L^{(T)} = \alpha K^{\alpha-1} \left[(1-\pi) + \pi\phi \right] \left\{ (1-\pi) + \pi\hat{\phi}^{\frac{1}{\alpha\eta-\alpha+1}} \phi^{\frac{\alpha(\eta-1)}{\alpha\eta-\alpha+1}} \right\}^{-1} f(\phi).$$

Similarly,

$$MPK_H^{(T)} = \hat{\phi}^{\frac{1}{1+\alpha\eta-\alpha}} \phi^{\frac{-1}{1+\alpha\eta-\alpha}} MPK_L^{(T)}.$$

QED.

C.4 Model guidance on empirical adjustment and extensions

Our two-period model in Section 3 provides precise guidance on the empirical adjustment to MPK, by correcting the amount of utilized capital in the denominator. For the numerator, however, our data sample Compustat does not include a direct measure of value-added in all years, nor does Compustat have information on firm-specific wage compensation.[50] Nevertheless, Compustat contains information on operating income (ex rental expense), which corresponds to $py - WL$. In our baseline model, $py - WL$ is equal to αpy. That is to say, operating income (ex rental expense) in Compustat corresponds to αpy. Hence, we can compute the adjusted mpk as the log difference between operating income (ex rental expense) (OIBDP+XRENT) and total utilized capital.[51]

[50] Note that the plant-level data used by Hsieh and Klenow (2009) includes a direct measure of value-added, but their measure for capital stock has neglected leased capital.

[51] This operating income (ex rental expense), OIBDP+XRENT, corresponds to the accounting variable EBITDAR - earnings before interest rate, depreciation, amortization, and rental expense. Indeed, as emphasized in Rauh and Sufi (2012), incorporating operating leases as a form of capital requires adding back the rental expense to operating cash flows.

Our analysis shows that there is another route of adjusting towards the true MPK - through adjusting the numerator while keeping the denominator at owned capital. The two-period model suggests that we may directly subtract the rental fees to adjust the numerator. This implies that the measure of MPK in Chen and Song (2013), which uses OIBDP in the numerator and PPENT in the denominator, is correct, as shown below:

$$MPK^{C.\&S.} = \frac{OIBDP}{Owned\ Capital} = \frac{(OIBDP + XRENT) - XRENT}{Owned\ Capital} = \frac{\alpha p_i y_i - \tau_l K_{i1}^l}{K_{i1}^o},$$

where $\alpha p_i y_i$ can be replaced by $\tau_l \left(K_{i1}^o + K_{i1}^l\right)$ when a firm starts to lease, indicating that $MPK^{C.\&S.}$ is equal to the per unit rental fee τ_l. This is the true MPK when a firm leases in the two-period model.

The above numerator adjustment suggests the *mpk* dispersion using Chen and Song (2013) should yield the same estimates with the adjusted measure using operating income (ex rental expense) and total utilized capital. Obviously, the equivalence between these two types of adjustment is inconsistent with the empirical evidence presented in Section 5.1.2.

In fact, this numerator adjustment type is subject to model specification errors and can be easily contaminated by different model extensions. We consider two model extensions - one under the monopolistic competition setup, as in our fully dynamic model case, while the other considers the fixed cost of renting capital. The detailed setup, optimality conditions, and MPK can be found in Appendix D.

These two simple extensions, along with our benchmark model, suggest various adjustments to the numerator. This confirms that model specification errors are indeed severe for the numerator adjustment. On the other hand, all model variations imply that the adjustment to the denominator is robust and subject to minimum (and reasonable) assumptions (e.g., the assumption that firms have the same market power within the same industry). There are no changes of model implications for misallocation, as misallocation is measured by within-industry dispersion of $\log(MPK)$. The implications on the mitigation effect of leasing are also preserved, since considering these additional features only creates gaps between total output and total cost, or, between marginal benefit and rental rate. We therefore conclude that our adjustment to the denominator is robust and should work best.

D Alternative setups for the two-period model

D.1 Alternative setup: Monopolistic competition

The first extension is the framework of monopolistic competition, consistent with Hsieh and Klenow (2009) and our dynamic setting. We keep all else the same as in our baseline two-period model, except that each firm now fully takes into account the impact of its production decision on price.

Setup

Final goods producer:

$$\max_{\{y_i\}} \left\{ Y - \int_{[0,1]} p_i y_i di \right\}_{Y = \left[\int_{[0,1]} y_i^{\frac{\eta-1}{\eta}} di \right]^{\frac{\eta}{\eta-1}}},$$

Intermediate goods producer: For each firm, we specify the profit maximization problem as:

$$\max_{C_{it},B_{i0},K^l_{i1},K^o_{i1},p_i} E\left[C_{i0} + R_f^{-1} C_{i1}\right],$$

$$C_{i0} + K^o_{i1} = N_0 + B_{i0},$$

$$C_{i1} = p_i y_i - \tau_l K^l_{i1} - R_0 B_{i0} + (1-\delta) K^o_{i1} - W L_i,$$

$$B_{i0} \leq \theta K^o_{i1},$$

$$K^o_{i1} \geq 0,$$

$$K^l_{i1} \geq 0,$$

$$C_{it} \geq 0, \quad (t = 0, 1)$$

$$y_i = z^T_{i1}\left(K^o_{i1} + K^l_{i1}\right)^{\alpha} L_i^{1-\alpha},$$

where $i = H, L$. Here firm i maximizes its utility by choosing the owned capital stock K^o_{i1}, borrowing from household B_{i0}, leased capital K^l_{i1}, labor L_i, the price p_i for its output, and its consumption C_{i0} and C_{i1}, subject to the budget constraint, the collateral constraint, the inverse demand function, and the law of motion for consumption in period 1.

Household:

$$\max_{C^H_0,C^H_1,B_0,K^l} E\left[\sum_{t=0}^{1} \beta^t u\left(C^H_t\right)\right],$$

$$s.t.: C^H_0 + B_0 + K^l_1 = \Omega_0,$$

$$\tau_l K^l_1 + (1-\delta-h) K^l_1 + R_0 B_0 + W = C^H_1.$$

Market clearing conditions

$$C_0^H + \int C_{i0}di + \int K_{i1}^o di + K_1^l = \Omega_0 + \int N_{i,0}di,$$
$$\int p_i y_i di + \int (1-\delta) K_{i1}^o di + (1-\delta-h)K_1^l = C_1^H,$$
$$B_0 = \int B_{i0}di,$$
$$K_1^l = \int K_{i1}^l di,$$
$$\int L_i di = 1.$$

Lagrangian

Final goods producer:

$$\max_{\{y_i\}} \left\{ Y - \int_{[0,1]} p_i y_i di \right\} = \left[\int_{[0,1]} y_i^{\frac{\eta-1}{\eta}} di \right]^{\frac{\eta}{\eta-1}} - \int_{[0,1]} p_i y_i di,$$

F.O.C. implies:

$$p_i = y_i^{-\frac{1}{\eta}} Y^{\frac{1}{\eta}}.$$

We next present the Lagrangian of firm i under our simplifying assumptions:

$$\begin{aligned}
\mathcal{L}_i \quad = \quad & \max R_f^{-1} C_{i1} \\
& + \eta_{i0} \left[\; N_0 + B_{i0} - K_{i1}^o \; \right] \\
+ \quad \eta_{i1} \quad & \left[\; y_i^{1-\frac{1}{\eta}} Y^{\frac{1}{\eta}} - \tau_l K_{i1}^l - R_f B_{i0} - C_{i1} + (1-\delta) K_{i1}^o - W L_i \; \right] \\
& + \xi_{i0} \eta_{i0} \left[\theta K_{i1}^o - B_{i0} \right] \\
& + \bar{\nu}_{i0} \eta_{i0} K_{i1}^o \\
& + \underline{\nu}_{i0} \eta_{i0} K_{i1}^l \\
& + d_{i1} C_{i1},
\end{aligned}$$

F.O.C.s:

$$[C_{i1}] : R_f^{-1} - \eta_{i1} + d_{i1} = 0, \tag{D42}$$

$$[K_{i1}^o] : -\eta_{i0} + \left[(1 - \frac{1}{\eta})\frac{\alpha p_i y_i}{K_{i1}^o + K_{i1}^l} + (1 - \delta)\right]\eta_{i1} + \theta\xi_{i0}\eta_{i0} + \bar{\nu}_{i0}\eta_{i0} = 0, \tag{D43}$$

$$[K_{i1}^l] : (1 - \frac{1}{\eta})\alpha\frac{p_i y_i}{K_{i1}^o + K_{i1}^l}\eta_{i1} - \tau_l\eta_{i1} + \underline{\nu}_{i0}\eta_{i0} = 0, \tag{D44}$$

$$[B_{i0}] : \eta_{i0} - R_f\eta_{i1} - \xi_{i0}\eta_{i0} = 0, \tag{D45}$$

$$[L_i] : (1 - \frac{1}{\eta})\,(1 - \alpha)\,\frac{p_i y_i}{L_i} = W, \tag{D46}$$

where d_{i1} must be zero since C_{i1} must be positive. In our setup, firms must always have owned capital, meaning that $\bar{\nu}_{i0}$ must be 0.

MPK

In this framework, the adjusted **true** MPK is:

$$MPK_{mono.}^{adj.} = \left(1 - \frac{1}{\eta}\right)\alpha\frac{p_i y_i}{K_{i1}^o + K_{i1}^l} = \left(1 - \frac{1}{\eta}\right)\alpha\frac{\textit{Value-Added}}{\textit{Total Capital}}.$$

In monopolistic competition, $py - WL$ is equal to $\left(\frac{1}{\eta} + \alpha\frac{\eta-1}{\eta}\right)py$. This corresponds to operating income (ex rental expense) in Compustat. Thus, we can compute the value-added as $\frac{OIBDP+XRENT}{\frac{1}{\eta}+\alpha\left(1-\frac{1}{\eta}\right)}$. We can then compute the adjusted MPK as the ratio of operating income (ex rental expense) to total utilized capital, multiplied by a constant, which depends on α and η. Since our focus is within-industry variation of firm outcomes, α and η are homogeneous within a single sector. The within industry $\log(MPK)$ dispersion will not be affected by the constant that consists of α and η.

With respect to the numerator adjustment, in monopolistic competition, the numerator OIBDP in Chen and Song (2013) only subtracts the marginal cost of leased capital, with the monopolistic rents created by leased capital remaining in the numerator. We can see this from the following equation:

$$MPK^{C.\&S.} = \frac{\textit{OIBDP}}{\textit{Owned Capital}} = \frac{\textit{(OIBDP+XRENT) - XRENT}}{\textit{Owned Capital}} = \frac{\left(\frac{1}{\eta} + \alpha\left(1 - \frac{1}{\eta}\right)\right) p_i y_i - \tau_l K_{i1}^l}{K_{i1}^o},$$

where $p_i y_i$ is equal to $\frac{1}{\alpha\left(1-\frac{1}{\eta}\right)}\tau_l\left(K_{i1}^o + K_{i1}^l\right)$ when a firm leases. This means that $MPK^{C.\&S.}$ is equal to:

$$\frac{\tau_l\left(K_{i1}^o + K_{i1}^l\right)\frac{\frac{1}{\eta}+\alpha(1-\frac{1}{\eta})}{(1-\frac{1}{\eta})\alpha} - \tau_l K_{i1}^l}{K_{i1}^o}.$$

It is obvious that $MPK^{C.\&S.}$ is larger than the rental fee per unit τ_l, which is the true MPK when a firm uses leased capital. In this case, $MPK^{C.\&S.}$ varies across firms with different leased capital ratios. The correct adjustment should hence subtract an additional term in the numerator. That is, we should use the following as the adjusted numerator:

$$\textit{[OIBDP+XRENT]}\frac{(1-\frac{1}{\eta})\alpha}{\frac{1}{\eta}+\alpha(1-\frac{1}{\eta})} - \textit{XRENT}.$$

D.2 Alternative setup: Fixed cost

In our second extension, we consider the model with a fixed cost of leasing. The fixed cost represents any additional cost relative to using owned capital, which is not included in rental fees. For example, the extra decoration costs for leased items could be one potential source. For simplicity's sake, we model it in a reduced form f_i for each unit of leased capital.

Setup

Final goods producer:

$$\max_{\{y_i\}}\left\{Y - \int_{[0,1]} p_i y_i di\right\}_{Y=\left[\int_{[0,1]} y_i^{\frac{\eta-1}{\eta}} di\right]^{\frac{\eta}{\eta-1}}}.$$

Intermediate goods producer: For each firm, we specify the profit maximization problem as:

$$\max_{C_{it},B_{i0},K^l_{i1},K^o_{i1}} E\left[C_{i0} + R_f^{-1} C_{i1}\right],$$

$$C_{i0} + K^o_{i1} = N_0 + B_{i0},$$

$$C_{i1} = p_i y_i - (\tau_l + f_i)K^l_{i1} - R_0 B_{i0} + (1-\delta)K^o_{i1} - W L_i,$$

$$B_{i0} \leq \theta K^o_{i1},$$

$$K^o_{i1} \geq 0,$$

$$K^l_{i1} \geq 0,$$

$$C_{it} \geq 0, \quad (t = 0, 1)$$

$$y_i = z^T_{i1}\left(K^o_{i1} + K^l_{i1}\right)^{\alpha} L_i^{1-\alpha}.$$

where $i = H, L$. Firm i's objective is to maximize its utility by choosing the owned capital stock K^o_{i1}, borrowing from household B_{i0}, leased capital K^l_{i1}, labor L_i, and its consumption C_{i0} and C_{i1}, subject to the budget constraint, the collateral constraint, and the law of motion for consumption in period 1.

Household:

$$\max_{C_0,C_1,B_0,K^l} E\left[\sum_{t=0}^{1} \beta^t u\left(C^H_t\right)\right],$$

$$s.t. : C^H_0 + B_0 + K^l_1 = \Omega_0,$$

$$\tau_l K^l_1 + (1-\delta-h)K^l_1 + R_0 B_0 + W = C^H_1.$$

Market clearing conditions

$$C_0 + \int C_{i0} di + \int K^o_{i1} di + K^l_1 = \Omega_0 + \int N_{i,0} di,$$

$$\int p_i y_i di + \int (1-\delta) K^o_{i1} di + (1-\delta-h) K^l_1 - \int f_i K^l_{i1} = C_1,$$

$$B_0 = \int B_{i0} di,$$

$$K^l_1 = \int K^l_{i1} di,$$

$$\int L_i di = 1.$$

Lagrangian

We present the Lagrangian of firm i under our simplifying assumptions:

$$\begin{aligned}
\mathcal{L}_i \quad = \quad & \max R_f^{-1} C_{i1} \\
& +\eta_{i0} \left[\; N_0 + B_{i0} - K^o_{i1} \; \right] \\
+ \quad \pi\eta_{i1} \quad & \left[\; p_i y_i - (\tau_l + f_i) K^l_{i1} - R_f B_{i0} - C_{i1} + (1-\delta) K^o_{i1} - W L_i \; \right] \\
& +\xi_{i0}\eta_{i0} \left[\theta K^o_{i1} - B_{i0} \right] \\
& +\bar{\nu}_{i0}\eta_{i0} K^o_{i1} \\
& +\underline{\nu}_{i0}\eta_{i0} K^l_{i1} \\
& +d_{i1} C_{i1}.
\end{aligned}$$

F.O.C.s:

$$[C_{i1}] : R_f^{-1} - \eta_{i1} + d_{i1} = 0, \tag{D47}$$

$$[K^o_{i1}] : -\eta_{i0} + \left[\frac{\alpha p_i y_i}{K^o_{i1} + K^l_{i1}} + (1-\delta) \right] \eta_{i1} + \theta \xi_{i0} \eta_{i0} + \bar{\nu}_{i0} \eta_{i0} = 0, \tag{D48}$$

$$[K^l_{i1}] : \alpha \frac{p_i y_i}{K^o_{i1} + K^l_{i1}} \eta_{i1} - (\tau_l + f_i) \eta_{i1} + \underline{\nu}_{i0} \eta_{i0} = 0, \tag{D49}$$

$$[B_{i0}] : \eta_{i0} - R_f \eta_{i1} - \xi_{i0}\eta_{i0} = 0, \tag{D50}$$

$$[L_i] : (1-\alpha)\frac{p_i y_i}{L_i} = W, \tag{D51}$$

where d_{i1} must be zero, since C_{i1} is sure to be positive. In our setup, firms must always have owned capital; hence, $\bar{\nu}_{i0}$ must be 0.

MPK

The adjusted **true** MPK is:

$$MPK^{adj.}_{f.} = \alpha \frac{p_i y_i}{K^o_{i1} + K^l_{i1}} = \alpha \frac{\textit{Value-Added}}{\textit{Total Capital}}.$$

In the model with an additional fixed cost, $py - WL$ is equal to αpy. That is to say, operating income (ex rental expense) in Compustat corresponds to αpy. Hence, we can compute the adjusted mpk as the log difference between operating income and total utilized capital.

In this case, the numerator in Chen and Song (2013) is also biased, in the sense that fixed cost associated with leasing is still kept in the numerator:

$$MPK^{C.\&S.} = \frac{\textit{OIBDP}}{\textit{Owned Capital}} = \frac{\textit{(OIBDP+XRENT) - XRENT}}{\textit{Owned Capital}} = \frac{\alpha p_i y_i - \tau_l K^l_{i1}}{K^o_{i1}},$$

where $\alpha p_i y_i$ can be replaced by $(\tau_l + f_i)\left(K^o_{i1} + K^l_{i1}\right)$, rather than $\tau_l\left(K^o_{i1} + K^l_{i1}\right)$. Therefore, the correct numerator in this specification should be:

$$\alpha p_i y_i - (\tau_l + f_i) K^l_{i1} = \textit{OIBDP} - f_i K^l_{i1}.$$

E Discussions on mismeasurement in aggregation and efficiency

As presented in the aggregation results of Sections 3.3 and 4.2, the adjusted MPK dispersion can be used to measure TFP losses. Here, we follow prior literature and study the aggregation when leased capital is utilized but ignored. We then compare these two aggregation results, ask whether similar results can be obtained using unadjusted MPK dispersion, and investigate the mismeasurements behind.

Under the assumptions of our two-period model, we can rewrite Eq. (4) and get:

$$y_i = \left[z_i^P z_i^T \left(\frac{K_i^o + K_i^l}{K_i^o} \right)^{\alpha} \right] \left(K_i^o\right)^{\alpha} L_i^{1-\alpha}. \tag{E52}$$

Given the fact that $\left(\frac{K_i^o+K_i^l}{K_i^o}\right)$ is larger or equal to 1, Eq. (E52) indicates that there will be overestimations of the measured firm-level productivity when the leased capital is ignored.[52] Correspondingly, the aggregate TFP without lease-adjustment is:

$$\text{TFP}^{\text{unadj.}} := \frac{\left[\int \left[z_i^P z_i^T \left(\frac{K_i^o+K_i^l}{K_i^o} \right)^{\alpha} \right]^{\eta-1} \left(MPK_i^{unadj.} \right)^{\alpha-\alpha\eta} di \right]^{\frac{1+\alpha\eta-\alpha}{\eta-1}}}{\left\{ \int \left[z_i^P z_i^T \left(\frac{K_i^o+K_i^l}{K_i^o} \right)^{\alpha} \right]^{\eta-1} \left(MPK_i^{unadj.} \right)^{\alpha-1-\alpha\eta} di \right\}^{\alpha}}. \tag{E53}$$

We now proceed to the mismeasured efficient allocation. Ignorant of leasing, the social planner reallocates all owned capital and labor to maximize total output. That is, the social planner equalizes the unadjusted MPK. This leads to the following unadjusted efficient TFP, which is augmented by the ratio of total utilized capital over the owned capital:

$$\text{TFP}^{\text{e, unadj.}} = \left(\int \left(z_i^P z_i^T \right)^{\eta-1} \left(\frac{K_i^o + K_i^l}{K_i^o} \right)^{\alpha(\eta-1)} di \right)^{\frac{1}{\eta-1}}. \tag{E54}$$

[52] Hu, Li, and Xu (2021) study in detail these measurements using various econometric methods.

The measured TFP losses are thus defined as:

$$\text{TFP losses}^{\text{ unadj.}} = \log \text{TFP}^{\text{e, unadj.}} - \log \text{TFP}^{\text{unadj.}}. \tag{E55}$$

If we assume that the measured firm productivity and measured unadjusted MPK follow a joint log normal distribution, Eq. (E55) can be reduced to:

$$\text{TFP losses}^{\text{ unadj.}} = \frac{1}{2}\alpha(\alpha\eta + 1 - \alpha)\,\text{var}\left(\log MPK_i^{unadj.}\right). \tag{E56}$$

Eq. (E56) suggests that the TFP losses (ignorant of leasing) monotonically increase in the extent of dispersion in (unadjusted) capital productivities, summarized by $\text{var}\left(\log MPK_i^{unadj.}\right)$. It is of similar form with Eq. (27), and it is exactly how the prior literature infers TFP losses.

If the log normality assumption both holds for the adjusted and unadjusted measures, we can directly translate the salient reduction of *mpk* dispersion (Section 5.1.2) into an overestimation (nearly 100%) of TFP losses inferred in the prior literature. This indicates that the US economy is more efficient in capital allocation than previously expected.

On the other hand, if the log normality assumption doesn't hold for either of the measure, we must interpret the results with additional caution. For example, if we assume that a joint log normal distribution holds for the true productivity and adjusted MPK while it doesn't hold for the the unadjusted measures, then Eq. (E56) is distorted and may no longer be applicable. In other words, whenever there exits unmeasured but utilized capital, the unadjusted MPK dispersion could be potentially delinked from the unadjusted TFP losses by simply multiplying $\frac{1}{2}\alpha(\alpha\eta+1-\alpha)$, in contrast to the traditional results suggested in prior studies.[53]

[53] Consequently, the drop in *mpk* dispersion after lease-adjustment may not be directly translated into the overestimation of TFP losses by multiplying $\frac{1}{2}\alpha(\alpha\eta + 1 - \alpha)$.

F Supplemental materials on causal evidence

This section provides additional causal evidence on the mitigating role of operating leases for capital misallocation induced by financial frictions.

F.1 Institutional backgrounds

The anti-recharacterization laws took place between 1997 and 2005. There are seven states that officially adopted the laws: Texas and Louisiana (1997), Alabama (2001), Delaware (2002), South Dakota (2003), Virginia (2004), and Nevada (2005). These new laws strengthen creditors' rights to repossess the collateral during bankruptcy within these seven jurisdictions. In particular, under anti-recharacterization laws, firms (the originators) first transfer collateral to an special purpose vehicle (SPV). The SPV generally has low risks and often remains solvent, even when the firms face bankruptcy and undergo restructuring. Meanwhile, these new laws require the courts to treat the collateral transfers to SPVs as true sales. Hence, after the implementation of such laws, the collateral under SPVs is exempted from the automatic stay because bankruptcy courts no longer have the discretion to recharacterize the collateral as a traditional loan. This enables creditors' rights for a swift seizure of collateral.

As such, the passage of the state laws serves as a quasi-natural experiment since the laws improve access to external financing and facilitate the pledgeability of assets for firms incorporated in these states (Li, Whited, and Wu, 2016; Mann, 2018; Favara, Gao, and Giannetti, 2018; Chu, 2020).[54]

[54] Although seven states enacted these laws, we only consider Texas, Louisiana, and Alabama, in which the anti-recharacterization laws were passed before 2002. Since the prominent case of *Reaves Brokerage Company, Inc., v. Sunbelt Fruit & Vegetable Company, Inc.*, there is evidence that these state-level anti-recharacterization laws could be partially affected by the federal law (Li, Whited, and Wu, 2016). However, some argue that the federal preemption is mainly on agricultural firms and on later adopters. Thus, to avoid noise, we only focus on three states that passed the law before 2002, and ignore the preemption. In untabulated results, we find that our results are robust.

F.2 Main specification

We estimate the following equation:

$$\begin{aligned}\text{MPK}_{ijst} = \beta_1 \text{Law}_{st} + \beta_2 \text{Law}_{st} \times I_i^{\text{High MPK}} + \beta_3 \text{Law}_{st} \times Access_j \\ + \beta_4 \text{Law}_{st} \times I_i^{\text{High MPK}} \times Access_j + \Gamma \mathbf{X_{it}} + \theta_i + \delta_t + \epsilon_{ijst},\end{aligned} \tag{F57}$$

where i denotes a firm, j denotes an industry, s denotes a state, and t denotes a year. Law_{st} is an indicator variable equal to one if firms are incorporated in Texas or Louisiana from 1997, and in Alabama from 2001. $I_i^{\text{High MPK}}$ is an indicator variable equal to 1 if a firm has a high pre-law (adjusted) MPK.[55] Next we define $Access_j$. Eisfeldt and Rampini (2009) point out that asset redeployability is the set of characteristics that determines how easy an asset can be leased; specifically, firms with higher asset redeployability are expected to get more access to leasing activities. We follow Kim and Kung (2017) to construct the asset redeployability. We then use the pre-law industry-level asset redeployability as a measure of $Access_j$. Alternatively, we use the pre-law average leased capital ratio at the industry level.

We include standard controls in $\mathbf{X_{it}}$, which are the natural logarithm of total assets, dividend, tangibility, cash to income ratio, tax rate, and debt leverage. θ_i and δ_t are firm and year fixed effects respectively. δ_t controls for aggregate fluctuations, while θ_i removes time invariant unobserved firm-level heterogeneity.

The coefficient of interest is β_4 - the coefficient for the triple interaction $\text{Law}_{st} \times I_i^{\text{High MPK}} \times Access_j$, which captures the differential effect of the policy on high MPK firms with more access to leasing markets. $\beta_4 > 0$ implies that the dependent variable (MPK) increases for high MPK firms relative to low MPK firms in treated states relative to non-treated states, for high relative to low leasing access.[56]

[55] We always use the adjusted MPK to classify high and low MPK firms prior to the laws. For the dependent variable, we study both adjusted MPK and unadjusted MPK (robustness checks) to check if our results are robust across different definitions.

[56] Our empirical identification is robust for the following reasons. In our specification, firm fixed effects help alleviate the bias generated from selection of treated firms. For measurement errors in MPK, firm fixed effects and year fixed effects account for systematic measurement errors at the firm and year level. In untabulated

F.3 Results

F.3.1 Average effects

We remove the interaction terms associated with $Access_j$ from Eq. (F57) and estimate the effect of the law on MPK for ex-ante high and low MPK firms with average leasing access. Columns (1) and (4) in Table F.2 present the results.

We find that β_2 is negative and statistically significant at the 1% level, meaning that high ex-ante MPK firms reduce MPK more relative to low MPK firms. That is, the laws lead to a decline of MPK dispersion.

F.3.2 Differential effects by ex-ante leasing access

Having established the fact that capital misallocation of firms incorporated in enacted states drop as compared with their counterparts in other states, we then estimate our main equation Eq. (F57) to examine the heterogeneous effects of ex-ante leasing access. The remaining columns (Columns (2), (3), (5), and (6)) in Table F.2 report the estimates.

We note that β_4 is always positive and statistically significant (at lease at the 5% level) for all specifications. It implies that MPK decreased less following the anti-recharacterization laws for high MPK firms with more access to leasing activities.[57]

Parallel trend conditions

To assess whether the results in Table F.2 are driven by pre-trends, we produce event

results, we find that our estimates are not sensitive to winsorizing extreme values of MPK. Eventually, the proxy for lease access is not subject to endogeneity, as we focus on pre-law averages and use the industry-level characteristics.

[57]In addition to being statistically significant, the magnitudes of the heterogeneous effects are economically meaningful. If we focus on the change in MPK (Column (5)), ex-ante high MPK firms whose leasing access is at the 25th percentile of the industry average redeployability distribution experience a decrease in MPK of 34% ($-0.81 + (1.33 \times 0.36)$). In contrast, high MPK firms whose industry average redeployability is at the 75th percentile of the distribution experience a decrease in MPK of 19% ($-0.81 + (1.33 \times 0.47)$). That is to say, the reduction at the 25th percentile is about twice that as the one at the 75th percentile. We obtain a similar conclusion when we measure a firm's lease accessability by using the industry average leased capital ratio, as presented in Column (6).

Table F.2

HETEROGENEITY BY LEASING ACCESS

Dependent variable: MPK	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
$\text{Law}_{st} \times I_i^{\text{High MPK}} \times Access_j$		1.52***	1.47***		1.33**	1.45***
		(3.95)	(6.58)		(2.15)	(4.57)
$\text{Law}_{st} \times I_i^{\text{High MPK}}$	-0.48***	-1.10***	-1.08***	-0.27***	-0.81***	-0.86***
	(-28.34)	(-7.88)	(-11.88)	(-11.42)	(-3.19)	(-7.59)
Law_{st}	0.19***	0.61***	0.54***	0.09***	0.60***	0.52***
	(12.04)	(28.05)	(29.35)	(3.35)	(8.16)	(17.16)
Controls	No	No	No	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of observations	46,374	46,374	46,358	43,001	43,001	41,991
Within R-sq	0.001	0.001	0.002	0.313	0.313	0.313

This table presents the results of heterogeneity by leasing access after the anti-recharacterization laws. The dependent variable is $\log(MPK)$, adjusted for lease. Law_{st} equals 1 for firms incorporated in Texas, Louisiana, or Alabama after the passing of the anti-recharacterization laws. Firms are classified as high MPK if their average adjusted MPK in the pre–law period is above the 4-digit industry mean. Leasing access is proxied using the 5-year average asset redeployability (Columns (2) and (5)) or average leased capital ratio (Columns (3) and (6)) at the industry level prior to the laws. Control variables include dividend, tangibility, cash to income ratio, tax rate, and debt leverage. Dividend equals 1 if the firm pays out a dividend (DVP + DVC > 0) and equals 0 otherwise; Tangibility is the net total property, plant, and equipment (PPENT) divided by total assets (AT); Cash to income ratio is the cash holding (CHE) divided by OIBDP; Tax rate is tax payment (TXT) to pretax income (PI); and Debt leverage is the ratio of the sum of long-term debt (DLTT) and debt in current liabilities (DLC) over the sum of leased capital and total assets (AT). The sample is from 1990 to 2010 and excludes financial, utility, public administrative, and lessor industries from the analysis. Firms that are not incorporated in the US and/or do not report in US dollars are also eliminated. Standard errors are two-way clustered at the state and year level. t-statistics are in parentheses. *, **, and *** denote 10, 5, and 1% statistical significance, respectively.

study graphs. We first rank firms according to their asset redeployability measures and assign to the high (low) access group firms in the bottom (top) quartiles of the asset redeployability measure. We then create indicator variables for being observed three years, two years before, and so on and interact these with being in a treated state, being a high MPK firm in a treated state, and being a high MPK firm with high access to leasing in a treated state. We include the same controls as in Table F.2. In Figure F.2, we present the relative effects by year of being a high MPK firm in a treated state for the log of MPK, for firms with high and low leasing access separately. The event year is defined to be 0 in 1997 for all firms except for those incorporated in Alabama, in which case the event year 0 is defined to be in the year 2001.

An important observation from the figure is that there is no obvious trend difference between the high and low leasing access firms before event year 0, suggesting that the parallel trend condition, the critical identification condition for our identification strategy, is likely to be satisfied. Another observation is that, following the shocks, high MPK firms with low leasing access change more aggressively relative to those with high leasing access, consistent with our estimates in Table F.2.

Altogether, the fact that the effects of the laws to reduce capital misallocation are smaller for firms who have (a priori) more access to leasing activities confirms that leasing mitigates capital misallocation induced by financial frictions.

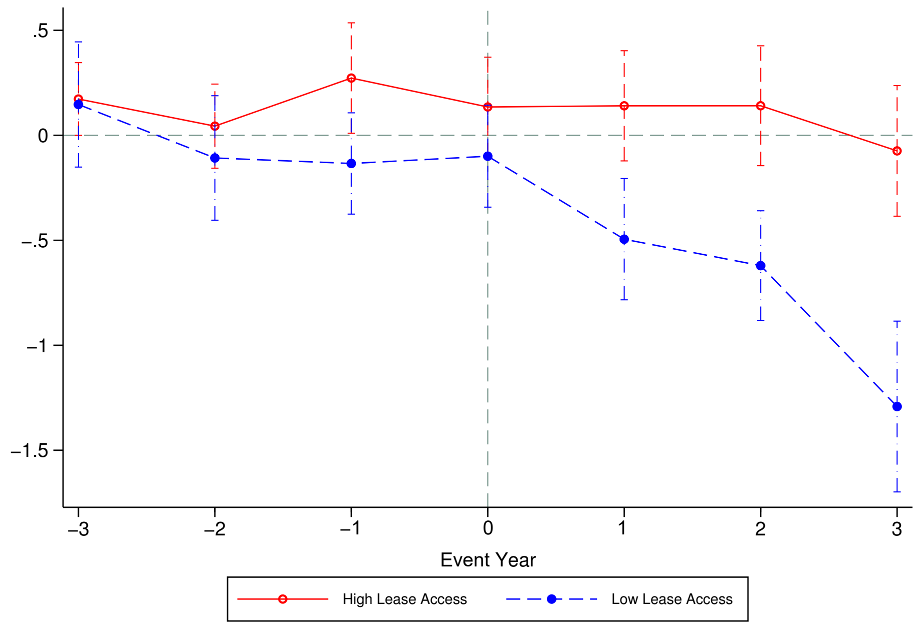
F.4 Robustness

Here, we change the dependent variable to unadjusted MPK, and report the results in Table F.3. There are two important messages. First, we find that the patterns found in the benchmark results are robust - following the implementation of the laws, (unadjusted) MPK dispersion drops and the drop is more salient for firms with less leasing access.

Second, and more importantly, the comparison between Table F.2 and Table F.3 is worth

Figure F.2

EVENT STUDY GRAPH FOR THE RELATIVE EFFECT OF ANTI-LAW ON HIGH MPK FIRMS WITH DIFFERENT LEASING ACCESS



This figure reports the event study graph for the relative effects of the anti-recharacterization laws on firms with high pre-treatment MPK relative to those with low pre-treatment MPK in treated states relative to untreated states, for firms with high and low leasing access separately. The event year is defined to be 0 in 1997 for all firms except for those incorporated in Alabama, in which case the event year 0 is defined to be in the year 2001. Each dot is the coefficient on the interaction term in our main specification. Leasing access is proxied using the 5-year average asset redeployability at the industry level prior to the laws. High leasing access refers to ex-ante high MPK firms whose leasing access at the 75th percentile of the redeployability distribution, while low leasing access refers to ex-ante high MPK firms whose leasing access at the 25th percentile of the redeployability distribution. The dependent variable is in log. The confidence intervals are at the 95% significance level.

mentioning. For the average effect, we see a larger drop when the dependent variable is unadjusted MPK, meaning that the effect of the laws in reducing misallocation has been overestimated. This finding is intuitive, as firms with high unadjusted MPK only take into account the owned capital in the denominator. The laws relax financial constraints, increasing owned capital while reducing leased capital; that said, only focusing on owned capital will naturally lead to a larger drop in high (unadjusted) MPK, and hence a larger drop in MPK dispersion. With respect to the heterogeneous effect, we find that for a one unit increase in $Access_j$, the increase in Row 1 for unadjusted MPK is lower, indicating a lower estimate of the mitigation role of leasing. This underestimation is consistent with the view that leasing is ignored in the unadjusted MPK. In sum, the overestimation of the average effect and underestimation of the heterogeneous effect come hand-in-hand, emphasizing the biases induced from ignoring leasing in measuring MPK.

G Supplemental materials on sensitivity analysis

In this section, we directly estimate the elasticity of substitution between the owned and leased capital, which strongly favors our perfect substitution assumption. We use the factor share approach (e.g., Chang (1994) and Eisfeldt, Falato, and Xiaolan (2021)).

Suppose that a firm produces using owned capital K^o, leased capital K^l, and labor L, according to a CES production function. We modify the CES form in Krusell et al. (2000) and Eisfeldt, Falato, and Xiaolan (2021) to accommodate leased capital:

$$y_{it} = f\left(z_{ip}, z_{it}, K_{it}^o, K_{it}^l, L_{it}\right) = z_{ip} z_{it} \left\{\alpha_c \left[\alpha_k (K_{it}^o)^\psi + (1-\alpha_k)\left(K_{it}^l\right)^\psi\right]^{\frac{\zeta}{\psi}} + (1-\alpha_c)\, L_{it}^\zeta\right\}^{\frac{1}{\zeta}}, \tag{G58}$$

where z_{ip} and z_{it} denote the permanent and transitory components of the firm productivity, respectively, and α_k and α_c are share parameters. ψ governs the elasticity of substitution γ between physical owned capital and leased capital (i.e.,$\psi = \frac{\gamma-1}{\gamma}$), whereas ζ governs the

Table F.3

HETEROGENEITY BY LEASING ACCESS (UNADJUSTED MPK)

Dependent variable: MPK	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
$\text{Law}_{st} \times I_i^{\text{High MPK}} \times Access_j$		1.21***	0.93***		1.14**	0.95***
		(4.04)	(7.96)		(2.20)	(3.18)
$\text{Law}_{st} \times I_i^{\text{High MPK}}$	-0.72***	-1.21***	-1.08***	-0.34***	-0.81***	-0.72***
	(-49.37)	(-9.89)	(-23.65)	(-8.08)	(-3.78)	(-8.26)
Law_{st}	0.31***	0.61***	0.52***	0.16***	0.64***	0.48***
	(10.47)	(16.88)	(9.99)	(2.92)	(4.19)	(5.58)
Controls	No	No	No	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of observations	51,773	51,773	51,745	48,057	48,057	48,031
Within R-sq	0.002	0.002	0.002	0.399	0.399	0.399

This table presents the results of heterogeneity by leasing access after the anti-recharacterization laws. The dependent variable is $\log(MPK)$, without adjusting for lease. Law_{st} equals 1 for firms incorporated in Texas, Louisiana, or Alabama after the passing of the anti-recharacterization laws. Firms are classified as high MPK if their average adjusted MPK in the pre–law period is above the 4-digit industry mean. Leasing access is proxied using the 5-year average asset redeployability (Columns (2) and (5)) or average leased capital ratio (Columns (3) and (6)) at the industry level prior to the laws. Control variables include dividend, tangibility, cash to income ratio, tax rate, and debt leverage, as in Table F.2. The sample is from 1990 to 2010 and excludes financial, utility, public administrative, and lessor industries from the analysis. Firms that are not incorporated in the US and/or do not report in US dollars are also eliminated. Standard errors are two-way clustered at the state and year level. t-statistics are in parentheses. *, **, and *** denote 10, 5, and 1% statistical significance, respectively.

elasticity of substitution ($\frac{1}{1-\zeta}$) between capital and labor. A unit value for ψ (or ζ) indicates perfect substitution, and a zero value indicates the same degree of complementarity as Cobb-Douglas.

Combine first-order conditions of firm maximization problem (as can be seen from our model) and the share of factor income, we know that:

$$\frac{s_{K^o,it}}{s_{K^l,it}} = \left(\frac{\alpha_k}{1-\alpha_k}\right)^{\frac{1}{1-\psi}} \left[\frac{R_{it}^{K^l}}{R_{it}^{K^o}}\right]^{\frac{\psi}{1-\psi}} \omega_{R,it}, \tag{G59}$$

where $R_{it}^{K^o}$ is the return to physical owned capital, and $R_{it}^{K^l}$ is the return to leased capital. These two returns are determined by households' first-order conditions. $s_{K^l,it}$ is the share of leased capital income, $s_{K^o,it}$ is the share of owned capital income, and $\omega_{R,it}$ is the fraction of leased capital income (relative the owned capital income) that is the marginal product. Eq. (G59) states that the difference between the trends of payments to physical owned capital and leased capital identifies the parameter ψ.

Then we add i.i.d. error terms to obtain our estimation equation:

$$\frac{s_{K^o,it}}{s_{K^l,it}} = \left(\frac{\alpha_k}{1-\alpha_k}\right)^{\frac{1}{1-\psi}} \left[\frac{R_{it}^{K^l}}{R_{it}^{K^o}}\right]^{\frac{\psi}{1-\psi}} \omega_{R,it} + u_{it} \tag{G60}$$

We confront this equation with the data to estimate the elasticity. Following Eisfeldt, Falato, and Xiaolan (2021), we construct factor shares using a merged NBER-CES-public-firm dataset. The merged dataset covers a broad set of manufacturing firms and contains a reliable measure of value-added. It consists of the NBER-CES Manufacturing Industry Database and the Compustat Database. Specifically, we calculate the owned capital share $s_{K^o,it}$ as the ratio of investment (NBER-CES) divided by value-added (NBER-CES). We calculate the leased capital share $s_{K^l,it}$ as the total income to leased capital divided by value-added (NBER-CES), where we proxy total income to leased capital using rental expenses, from the merged NBER-CES-public-firm dataset. Because the NBER-CES data covers all public and private firms, while Compustat covers only public firms, we adjust the differential coverage by scaling our rental income share by the ratio of sales in Compustat to the ratio of sales in the NBER-CES data at the industry level. Finally, we rely on the FOCs of firms to calculate $R_{it}^{K^o}$ using the depreciation rate estimated from the Bureau of Economic Analysis (BEA) data, the investment goods prices from NBER-CES, as well as time series of real interest rates, as implied by the FOCs of firms.

We now describe our identification strategy. We first assume $\omega_{R,it}$ and $R_{it}^{K^l}$ are either fixed across time, or across industries, since both of them are unobservable. Then we take logs to Eq. (G60) and get the following specification:

$$\log s_{K^l,it} - \log s_{K^o,it} = \frac{1}{1-\psi} \log\left(\frac{1-\alpha_k}{\alpha_k}\right) + \frac{\psi}{1-\psi} \log R_{it}^{K^o} - \frac{\psi}{1-\psi} \log R_i^{K^l} + \log \frac{1}{\omega_{R,t}} + \log u_{it} \tag{G61}$$

where i denotes an industry. Both year fixed effects and industry fixed effects are included in the estimation to absorb $\omega_{R,t}$ and $R_i^{K^l}$. Our interpretation of the specification as assuming that 1) $\omega_{R,t}$ is identical across industries but varies over time; and 2) $R_i^{K^l}$ is different across industries by identical over time. Therefore, we can identify ψ from the coefficient on $\log R_{it}^{K^o}$.[58]

Using the data ranging from 1977 to 2017, we find evidence of a strong degree of substitutability between physical owned and leased capital. The estimated coefficient on $\log R_{it}^{K^o}$ is 3.12 and is highly significant (t-statistic of 9.33). This estimate implies that the elasticity of substitution between physical capital and human capital is quite high, i.e., $\gamma = 4.12$.

This finding on the substitutability between owned capital and leased capital is in favor of our perfect substitution assumption. In practice, the new lease accounting standards require firms to report lease-induced assets under fixed assets on the balance sheets, also with a perfect substitution assumption (Appendix A.2). Hence, the perfect substitution

[58] An alternative assumption that $R_i^{K^l}$ varies over time but is constant across industries, while ω_R is constant over time but varies across industries leads to the same estimation result for ψ.

assumption is both consistent with the theory (e.g., Eisfeldt and Rampini (2009) and Rampini and Viswanathan (2013)) and with the data.

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