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The firm-level credit multiplier ☆

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ABSTRACT

We study the effect of asset tangibility on corporate financing and investment decisions. Financially constrained firms benefit the most from investing in tangible assets because those assets help relax constraints, allowing for further investment. Using a dynamic model, we characterize this effect — which we call *firm-level credit multiplier* — and show how asset tangibility increases the sensitivity of investment to Tobin's *Q* for financially constrained firms. Examining a large sample of manufacturers over the 1971–2005 period as well as simulated data, we find support for our theory's tangibility–investment channel. We further verify that our findings are driven by firms' debt issuance activities. Consistent with our empirical identification strategy, the firm-level credit multiplier is absent from samples of financially unconstrained firms and samples of financially constrained firms with low spare debt capacity.

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1. Introduction

The interplay between real and financial decisions is a central issue in corporate finance research. Accordingly, a large body of literature examines when firms should invest and how they should finance their projects. The literature, however, often fails to appreciate the impact of contracting frictions on firms' ability to raise funds for investment. As a result, the investment process is generally taken as *exogenous* to firms' financial status and financing decisions.

Financing frictions manifest themselves in many different ways. They typically make it harder for firms to raise fairly-priced funds to finance their projects. As a result, the availability of financing — rather than the availability of investment opportunities — drives firms' investment spending. Some of the most commonly observed financing frictions stem from the limited enforceability of contracts, especially in poor states of the world. Evidence suggests that firms strategically default on their contractual obligations when liquidation values are too low to keep investors committed to termination (Gilson et al., 1990; Altman, 1991). Theoretical models recognize this problem and characterize financing arrangements that commit investors to costly termination outcomes (see Harris and Raviv, 1990; Bolton and Scharfstein, 1990). Although they vary in their design, the element that makes these contracts enforceable has a common real-world counterpart: the salability or "tangibility" of the company's assets.[1] The tangibility of corporate assets is not only tied to the firm's investment process (asset tangibility is a function of the firm's line of business and capital accumulation process), but also to the firm's ability to raise external funds.

This paper explores an inherent attribute of the firm — the tangibility of its operating assets — to characterize an *endogenous* relation between firms' real and financial decisions in the presence of financing imperfections. The tangibility of a firm's assets affects its ability to pledge collateral, which serves as creditors' "enforceable" outside option in contract renegotiations. As such, asset tangibility reduces debtors' incentive to default strategically, enlarging the firm's debt capacity. While variants of the asset tangibility–investment channel have been described in prior work in macroeconomics (see Kiyotaki and Moore, 1997; Bernanke et al., 2000), the idea has not been articulated in a firm-level setting. The extant literature lacks a theory with implications for cross-sectional investment as well as empirical tests for the real effects of contract enforceability frictions.

We argue that firms that face financing frictions can benefit the most from the larger debt capacity that is created by tangible assets. In particular, access to more (or cheaper) credit allows firms to invest more without resorting to costly external equity or public unsecured debt. We show that the additional investment — in tangible assets — further relaxes constraints, albeit at a diminishing rate. In this way, investment is amplified by a financing feedback of asset tangibility that arises endogenously in the presence of contracting frictions. Our analysis formalizes the mechanism through which asset tangibility amplifies the impact of shocks to the firm's opportunity set onto the firm's investment and financing across time. We call this mechanism the *firm-level credit multiplier*. The mechanism we characterize arises from the interplay between asset tangibility, renegotiable bank debt, costly equity financing, and investment and differs from the economy-wide credit multiplier discussed in the macroeconomics literature. As we discuss below, the firm-level credit multiplier yields a number of new testable predictions, such as the increased sensitivity of investment to Tobin's Q for financially constrained firms.

The dynamic model we use is uniquely suitable for the purpose of our analysis. Among other features, it allows us to compute security values, characterize dynamic aspects of the credit multiplier, and gauge the impact of financing–investment interactions upon a number of variables that are of wide interest for empirical research (e.g., Q and debt issuance). In addition to closed-form solutions for constrained and unconstrained firm values and financing–investment strategies, the model enables us to simulate artificial panel data sets and conduct cross-sectional tests similar to those later performed in our empirical tests (based on COMPUSTAT data).

[1] Hereinafter, the term "asset tangibility" is generally adopted and meant to summarize the *liquidation value* and *ease of redeployment* of a firm's capital from the perspective of outside creditors in the event of default.

Our model's central results guide us in performing novel empirical tests on the extensively studied relation between corporate investment and Q. The model shows, for example, that the impact of the credit multiplier on investment is only significant for firms that face financing frictions and that it increases with the degree of tangibility of those firms' assets. Empirically, both Q and asset tangibility are expected to affect investment behavior, but the model's credit multiplier effect implies that the *interaction* of these two variables will have a strong positive impact on investment in a cross-section of financially constrained firms. Put differently, our theory predicts that positive innovations to investment prospects prompt stronger responses in observed capital spending when the firm solves a constrained optimization problem and its assets are more tangible.

We test our theory using a large sample of manufacturers over the 1971–2005 period. As is standard in the corporate investment literature, we identify the predictions of our model based on comparisons between firms that are likely to be more financially constrained ("constrained firms") and firms that are likely to be less constrained ("unconstrained firms"). We employ multiple schemes to partition the data into constrained and unconstrained subsamples. These are based on firm characteristics, such as payout policy, firm size, and debt ratings (bond and commercial paper ratings).

For each constraint partition scheme, we find that asset tangibility promotes investment through a credit multiplier effect for constrained firms, but not for unconstrained firms. As discussed above, because of the role of asset tangibility in simultaneously boosting financing and investment, our theory implies that the credit multiplier will be finely identified in the cross-section by interacting asset tangibility with Q. Consistent with this prediction, our tests show that estimates for this interaction term reliably explain investment across financially constrained firms. Moreover, we find that this interaction effect is even more pronounced in a more refined set of tests in which we split constrained firms into subsamples with low and high incremental (or "spare") debt capacity. In particular, in line with our theory, we find that constrained firms with largely untapped debt capacity display the strongest relation between investment and asset tangibility interacted with Q. Notably, none of the effects just described are found in the cross-section of financially unconstrained firms.

We perform an exhaustive round of checks to verify that our results also obtain under alternative test specifications and methods. We show, for example, that our results do not rely on *a priori* assignments of firms into financing constraint categories, such as those based on observables like firm size and debt ratings. In particular, we also estimate switching regressions in which the probability that firms face constrained access to credit is jointly estimated with the structural investment equations — i.e., constraint assignments are *endogenous* to investment. Our results also obtain when we use maximum likelihood estimations (switching regressions), GMM estimations, and error-consistent estimations in which Q is replaced with Cummins et al.'s (2006) *RealQ*. Under each of these alternative tests, the impact of asset tangibility on constrained firms' financing–investment interactions remains economically and statistically significant.

To further characterize our proposed mechanism, we also look at the effect of asset tangibility on financing decisions. Surprisingly, there is only limited empirical work on the link between tangibility and capital structure. Existing studies largely document a positive correlation between the ratio of fixed-to-total assets and financial leverage.[2] The evidence in the literature is consistent with the idea that asset tangibility matters for raising external financing. However, existing papers do not investigate the role of asset tangibility in underlying a channel between financial contracting and real-side investment. Our tests show that asset tangibility magnifies the effect of shocks to investment opportunities onto debt issuance when firms are financially constrained, but not when they are unconstrained. In other words, the tangibility-led amplification effect that is found for investment spending is also observed for debt policies when firms face financing frictions. The evidence we report for leverage decisions agrees with the predictions of our credit multiplier theory.

The papers closest to ours are Almeida and Campello (2007) and Hennessy et al. (2007). Almeida and Campello find that cash flow has a larger impact on investment when assets are more tangible.

[2] One exception is a recent paper by Campello and Giambona (2011), who show that the redeployability of tangible assets has a causal impact on corporate leverage.

In contrast to their empirical paper, we develop a model of the role played by asset tangibility in underlying an endogenous link between financing and investment in the presence of financing imperfections. Moreover, our analysis shows how debt policies (e.g., debt issuance) are affected by asset tangibility, while their study provides no characterization of firm financial policies. Hennessy et al. analyze Q theory with financing frictions for firms using risk-free debt and costly external equity. In contrast, our model encompasses mixtures of risky debt and costly external equity. Their study is silent on the credit multiplier and its implications, which is the focus of our analysis.

The rest of the paper is organized as follows. Section 2 studies a dynamic model of financing and investment. Section 3 discusses data and empirical methodology. Section 4 tests our theory's main predictions. Section 5 concludes.

2. Theory

2.1. Setup

Time is continuous and the horizon is infinite. Consider a firm that has a growth option but no assets-in-place and no outstanding debt.[3] At any point in time $t \geqslant 0$, the firm may exercise its option by paying a fixed cost K in exchange for receiving uncertain cash flows. This exercise cost of the growth option can be financed by debt, equity, or a mixture of debt and equity. Potential cash flows from option exercise are subject to productivity shocks and evolve over time according to a geometric Brownian motion, X_t, with drift μ, volatility σ, and initial value $X_0 > 0$. The firm is risk-neutral and discounts at the risk-free rate $r > \mu$.

We model the pledgeability of the firm's assets (i.e., the value of the exercised growth option V) by assuming that the transfer of the firm's physical assets in bankruptcy entails costs that are proportional to those assets. If the firm's assets are seized by its creditors, only a fraction, $\tau V < V$, of the firm's physical capital is recovered. τ is a function of the nature of the firm's assets (e.g., assets such as land and machinery are easier to verify and foreclose than patents and trademarks), as well as industry characteristics, such as capital utilization rates and used capital redeployability.

The firm can finance the exercise cost with a mix of bank debt, which is renegotiable, and external equity. Bank debt promises a contractual payment of b unless the firm is liquidated (i.e., claims are settled and the proportion of tangible firm value, τ, is transferred to the bank). As we allow for renegotiation of the debt contract, strategic default optimally occurs when cash flows decline sufficiently.[4] At that point, equityholders keep control of the firm and make take-it or leave-it offers to the bank, which results in strategic instead of contractual debt payments until cash flows rise again.

Finally, external equity funding of the capital expenditure, K, is costly if the firm faces financial frictions; i.e., the firm cannot find fairly-priced funding for its profitable investment opportunity.[5] In particular, each equity-financed \$1 of the capital expenditure leads to an exercise cost of $\$(1+\imath)$for the *constrained* firm, where $\imath > 0$ represents the linear component of equity issuance costs, while each equity-financed \$1 for the *unconstrained* firm leads to an exercise cost equal to \$1.[6]

2.2. Solution

We work recursively by first solving for firm value after investment, V. We then determine bank debt value after investment, B. A prerequisite for this bank debt valuation is the characterization of

[3] This allows us to abstract from the debt overhang problem analyzed in an extensive literature (see, e.g., Chen and Manso (2010), Hackbarth and Mauer (forthcoming), and the references therein).

[4] See, for example, Mella-Barral and Perraudin (1997), Fan and Sundaresan (2000) and Hackbarth et al. (2007), where liquidation is also inefficient but, in equilibrium, bilateral bargaining eliminates liquidation.

[5] See Bernanke et al. (2000) for models on how financing frictions influence macroeconomic dynamics.

[6] For simplicity and tractability, floatation costs are normalized to zero for the unconstrained firm in that we can regard financing frictions as a relative statement about issuance costs of constrained and unconstrained firms. The numerical simulations we carry out below do not require algebraic tractability. So we will add quadratic issuance costs for constrained firms as suggested by Altinkilic and Hansen (2000) as well as much smaller, linear floatation costs for unconstrained firms to reinforce the robustness of our model's main prediction.

the optimal strategic debt service when the firm has the ability to make take-it or leave-it offers to the bank. We value the constrained firm and the unconstrained firm at time zero, which allows us to derive their value-maximizing investment strategies.

The firm's value after investment is given by:

$$V(X) = UX, \tag{1}$$

where X denotes the current cash flow and $U \equiv 1/(r-\mu)$ denotes the growth-adjusted, risk-neutral discount factor. Consequently, the value of the firm in case of bankruptcy (i.e., liquidation) equals:

$$L(X) = \tau V(X). \tag{2}$$

In case of renegotiation, equityholders make take-it or leave-it offers to the bank. Since the bank can reject an offer, the bank's payoff in case of bankruptcy, L, represents its outside option in the bargaining game with the firm. Outside of renegotiation, the bank can claim at the most the present value of the contractual payments. Thus, the bank's reservation value function is

$$R(X) = \min\left\{\frac{b}{r}, L(X)\right\} \tag{3}$$

given that it would reject any debt service offer yielding a lower payoff than R.

On the one hand, strategic debt payments, s, must be sufficient to induce acceptance by the bank; i.e., $B(X) \geqslant R(X)$. On the other hand, there must exist an incentive for the firm to make strategic rather than contractual debt payments; i.e., $s < b$. The latter observation implies an interval, $[\underline{X}, \infty)$, such that no renegotiation occurs above an endogenously determined renegotiation threshold, $\underline{X}$. Since equity's dividends are decreasing in the strategic debt service, the former observation implies that $B(X) = R(X)$ over the interval $(0, \underline{X})$ where renegotiation occurs.[7]

In the renegotiation region, the bank's claim B pays s and offers capital gains $\mathrm{E}[dB(X)]$ over each time interval dt. The required rate of return for holding this claim is the risk-free rate r. Therefore, the Bellman equation for all $X \in (0, \underline{X})$ is:

$$r\ B(X)\ dt = \mathrm{E}[dB(X)] + s\ dt, \tag{4}$$

where $\mathrm{E}[\cdot]$ is the expectation operator. Applying Ito's lemma to the right-hand side of this equation, it follows that the bank debt value satisfies for all $X \in (0, \underline{X})$ the ordinary differential equation:

$$r\ B = \mu X\ B_X + \tfrac{1}{2}\sigma^2 X^2\ B_{XX} + s, \tag{5}$$

where subscripts denote partial derivatives. Substituting R and its derivatives for B implies that, in the renegotiation region, strategic debt service is linear in X, taking the form: $s(X) = \tau X$.

Similar arguments imply that the bank debt value satisfies for all $X \in [\underline{X}, \infty)$:

$$r\ B = \mu X\ B_X + \tfrac{1}{2}\sigma^2 X^2\ B_{XX} + b. \tag{6}$$

The solution of Eq. (6) is $B(X) = A_1 X^{\beta} + A_2 X^{\nu} + \frac{b}{r}$ where $\beta > 1$ and $\nu < 0$ are the positive and negative roots of the quadratic equation: $Q(\xi) \equiv \frac{1}{2}\xi(\xi-1)\sigma^2 + \xi\mu - r = 0$. The constants A_1 and A_2 are determined by the value-matching conditions $B(\underline{X}) = L(\underline{X})$ and $\lim_{X\to\infty} B(X) = \frac{b}{r}$. These conditions yield the following bank debt value function:

$$B(X) = \begin{cases} \tau\ V(X) & \text{if } X \in (0, \underline{X}), \\ \frac{b}{r} - \left(\frac{b}{r} - \tau\ V(\underline{X})\right)\left(\frac{X}{\underline{X}}\right)^{\nu} & \text{if } X \in [\underline{X}, \infty). \end{cases} \tag{7}$$

[7] We confine attention to strategic debt service functions that are piecewise right-continuous in X (see, e.g., Mella-Barral and Perraudin (1997) or Hackbarth et al. (2007) for more details).

To determine the optimal renegotiations strategy, consider starting at an arbitrarily high value of X where the payment of b is made. In choosing the renegotiation threshold, $\underline{X}$, equityholders find the highest cash flow level such that an offer $s(X)$ is accepted by the bank in the left neighborhood of $\underline{X}$. This reduces the optimal renegotiation strategy to a smooth-pasting condition:

$$\lim_{X\uparrow\underline{X}} B_X = \lim_{X\downarrow\underline{X}} B_X \tag{8}$$

Solving Eq. (8) yields equity's strategic switch point for entering into renegotiations with the bank:

$$\underline{X} = \left(\frac{r-\mu}{r}\right)\left(\frac{\nu}{\nu-1}\right)\left(\frac{b}{\tau}\right). \tag{9}$$

Finally, the value of equity equals, in each of the two regions, the firm's value less the value of bank debt. This firm value identity implies the following equity value function after investment:

$$S(X) = \begin{cases} (1-\tau)\ V(X) & \text{if } X \in (0, \underline{X}). \\ \left(V(X) - \frac{b}{r}\right) + \left(\frac{b}{r} - \tau\ V(\underline{X})\right)\left(\frac{X}{\underline{X}}\right)^{\nu} & \text{if } X \in [\underline{X}, \infty). \end{cases} \tag{10}$$

We next solve the unconstrained firm's investment problem. This is not only a useful benchmark, but also an ingredient of the constrained firm's investment problem. Working backwards, the value of the unconstrained firm prior to investment, F^u, equals the expected present value of equity value at the time of investment, $\mathcal{T}^u$, minus the capital expenditure net of bank debt value issued at time $\mathcal{T}^u$. Thus, the firm invests to maximize the value of its option:

$$F^u(X) = \sup_{\mathcal{T}^u} \ \mathrm{E}\left[e^{-r\mathcal{T}^u}(S(X_{\mathcal{T}^u}) - (K - B(X_{\mathcal{T}^u})))\right]. \tag{11}$$

Because the firm does not produce any cash flows before investment, owners only receive capital gains of $\mathrm{E}[dF^u(X)]$ over each time interval dt. The required rate of return for investing in the unconstrained firm is the risk-free rate r. Therefore, the Bellman equation in the continuation region is:

$$r\ F^u(X)\ dt = \mathrm{E}[dF^u(X)]. \tag{12}$$

Applying Ito's lemma to the right-hand side of Eq. (12) implies that the value of the unconstrained firm prior to investment satisfies the ordinary differential equation:

$$r\ F^u = \mu X\ F^u_X + \tfrac{1}{2}\ \sigma^2 X^2\ F^u_{XX}. \tag{13}$$

Eq. (13) has the general solution $F^u(X) = A_1 X^{\beta} + A_2\ X^{\nu}$, which is subject to three boundary conditions. First, the value of the unconstrained firm upon investing is equal to the payoff from investing:

$$F^u(\widehat{X}^u) = S(\widehat{X}^u) - (K - B(\widehat{X}^u)), \tag{14}$$

where $\widehat{X}^u$ denotes the unconstrained firm's investment threshold. In the absence of frictions, Eqs. (7) and (10) imply that the unconstrained firm's value-matching condition in Eq. (14) simplifies to:

$$F^u(\widehat{X}^u) = V(\widehat{X}^u) - K. \tag{15}$$

Second, as cash flows tend to zero, the option to invest becomes worthless so that it satisfies: $\lim_{X\to 0} F^u(X) = 0$. Third, to ensure that investment occurs along the optimal path, the unconstrained firm's optimal investment threshold, $\widehat{X}^u$, is the one that maximizes the unconstrained firm' option value to invest. Solving the unconstrained firm's problem yields the following proposition.

Proposition 1. *The unconstrained firm's value-maximizing investment strategy is:*

$$\widehat{X}^u = K\ (r-\mu)\left(\frac{\beta}{\beta-1}\right), \tag{16}$$

where $\beta > 1$ is the positive root of the quadratic equation: $Q(\xi) \equiv \frac{1}{2}\xi(\xi-1)\sigma^2 + \xi\mu - r = 0$. For all $X \leqslant \widehat{X}^u$, the unconstrained firm's value is given by:

$$F^u(X) = K^{1-\beta}\left(\frac{1}{\beta-1}\right)^{1-\beta}\left(\frac{X}{\beta(r-\mu)}\right)^{\beta}. \tag{17}$$

The results in Eqs. (16) and (17) reveal that asset tangibility is irrelevant for the unconstrained firm.

Perhaps surprisingly, the unconstrained firm's solution is invariant to asset tangibility even though it also utilizes a mixture of renegotiable bank debt and equity to finance investment. Proposition 1 characterizes some basic and realistic features of financing–investment dynamics of the unconstrained firm. In the absence of financing frictions, the features of the benchmark case are also typical for models with all-equity financing of the exercise cost (see Dixit and Pindyck, 1994). For example, because the exercise payoff increases with the growth rate of cash flows, μ, and decreases with the exercise cost, K, the value-maximizing investment threshold of the unconstrained firm, $\widehat{X}^u$, declines with μ and rises with K. During a given time interval $[0,T]$, the dynamic model implies that the investment hazard (i.e., the likelihood of reaching an investment point, at which the option to invest is optimally exercised) rises with $\mu$and declines with K.[8] Similarly, a greater volatility for the changes in X produces more uncertainty over the value of the exercise payoff and hence an increased incentive to wait since the hysteresis term, $\frac{\beta}{\beta-1}$, is an increasing function of σ.

Similar arguments apply to the derivation for the constrained firm. That is, the value of the constrained firm prior to investment satisfies the following ordinary differential equation:

$$r\ F^c = \mu X\ F^c_X + \tfrac{1}{2}\sigma^2 X^2\ F^c_{XX}, \tag{18}$$

which is again solved subject to suitable boundary conditions. First, the value of the constrained firm upon investing equals the payoff from investing net of equity issuance costs if applicable:

$$F^c(\widehat{X}^c) = S(\widehat{X}^c) - (K - B(\widehat{X}^c)) - \imath(K - B(\widehat{X}^c))1_{K>B(\widehat{X}^c)}, \tag{19}$$

where $\widehat{X}^c$ denotes the constrained firm's investment threshold and 1_ω represents the indicator function of the event ω. Since bank debt is renegotiable and, in equilibrium, bilateral bargaining eliminates liquidation, the firm utilizes the largest available value of $B(\widehat{X}^u)$ in Eq. (19) to economize on external equity issuance costs. Notice that, even though $\partial B(X)/\partial b \geqslant 0$, there exists a bank debt capacity for an arbitrary cash flow level, X, in the following sense:

$$\exists\ b^{\max}\ \text{s.t.}\ \underline{X}(b^{\max}) = X \Rightarrow B(X) = B(\underline{X}) = R(X). \tag{20}$$

Intuitively, there is a critical bank coupon capacity, $b^{\max}(X)$, beyond which raising promised payments to the bank cannot raise bank debt value. Thus, the optimal bank debt coupon is given by:

$$b^{\max}(X) = \left(\frac{r}{r-\mu}\right)\left(\frac{\nu-1}{\nu}\right)\tau X. \tag{21}$$

Importantly, this bank debt capacity is an increasing function of asset tangibility, which plays an important role for the constrained firm. Substituting Eq. (21) into Eq. (7) and evaluating at $X = \widehat{X}^u$ yields an endogenous "quantity constraint" in the spirit of Hart and Moore (1994) in that $B(\widehat{X}^c)|_{b=b^{\max}(\widehat{X}^c)} = R(\widehat{X}^c)$ for optimal bank debt financing at the endogenously selected time of investment. Second, as cash flows tend to zero, the option to invest becomes worthless so that it satisfies: $\lim_{X\to 0}F^c(X) = 0$. Third, to ensure that investment occurs along the optimal path, the constrained firm's optimal investment threshold, $\widehat{X}^c$, is the one that maximizes the constrained firm' option value to invest. Solving the constrained firm's problem yields the following proposition.

[8] The probability that the unconstrained firm exercises its investment option in a time interval $[0,T]$ is given by:

$$\Pr\left(\sup_{0\leqslant XT^u\leqslant T} X_{T^u} \geqslant \widehat{X}^u\right) = \Phi\left(\frac{\ln(X/\widehat{X}^u) + (\mu - \sigma^2/2)T}{\sigma\sqrt{T}}\right) + \left(\frac{X}{\widehat{X}^u}\right)^{1-2\mu/\sigma^2}\Phi\left(\frac{\ln(X/\widehat{X}^u) - (\mu - \sigma^2/2)T}{\sigma\sqrt{T}}\right),$$

where $\Phi(\cdot)$ is the standard normal distribution. This probability declines with the investment threshold $\widehat{X}^u$

Proposition 2. *The constrained firm's value-maximizing investment strategy is:*

$$\widehat{X}^c = \begin{cases} \widehat{X}^u & \text{if } \tau \in [\overline{\tau}, 1), \\ K\ (r-\mu)\left(\frac{1}{\tau}\right) & \text{if } \tau \in [\underline{\tau}, \overline{\tau}), \\ K\ (r-\mu)\left(\frac{1+\iota}{1+\iota\tau}\right)\left(\frac{\beta}{\beta-1}\right) & \text{if } \tau \in [0, \underline{\tau}), \end{cases} \tag{22}$$

where $\widehat{X}^u$ *is given in (16),* $\overline{\tau}$ *is the value of* τ *that solves the non-linear equation:*

$$\overline{N}(\tau) \equiv \left(\frac{1}{\beta-1}\right)^{1-\beta}\left(\frac{1}{\beta\tau}\right)^{\beta} - \left(\frac{1-\tau}{\tau}\right) = 0, \tag{23}$$

and where $\underline{\tau}$ *is the value of* τ *that solves the non-linear equation:*

$$\underline{N}(\tau) \equiv \left(\frac{1+\iota}{\beta-1}\right)^{1-\beta}\left(\frac{1+\iota\tau}{\beta\tau}\right)^{\beta} - \left(\frac{1-\tau}{\tau}\right) = 0. \tag{24}$$

For all $X \leqslant \widehat{X}^c$*, the constrained firm's value is given by:*

$$F^c(X) = \begin{cases} F^u(X) & \text{if } \tau \in [\overline{\tau}, 1), \\ K^{1-\beta}\left(\frac{1-\tau}{\tau}\right)\left(\frac{\tau X}{r-\mu}\right)^{\beta} & \text{if } \tau \in [\underline{\tau}, \overline{\tau}), \\ K^{1-\beta}\left(\frac{1+\iota}{\beta-1}\right)^{1-\beta}\left(\frac{(1+\iota\tau)X}{\beta(r-\mu)}\right)^{\beta} & \text{if } \tau \in [0, \underline{\tau}), \end{cases} \tag{25}$$

where F^u *is given in Eq. (17). The results in Eqs. (22) and (25) reveal that asset tangibility is relevant for the constrained firm.*

Proposition 2 describes the financing–investment dynamics of the constrained firm, which employs — like the unconstrained firm — a mixture of debt and equity to finance the growth option. The proposition highlights several interesting features of corporate financing and investment in the presence of financing imperfections. First, a comparison between Propositions 1 and 2 indicates that asset tangibility is irrelevant for the solution of the unconstrained firm's optimization problem. However, Proposition 2 reveals that the interaction between asset tangibility and contracting frictions plays a critical role in the solution of the constrained firm's optimization problem.

Second, the first case in Eq. (22) formalizes the intuition that asset tangibility can relax financing constraints in the "high" tangibility region. For a sufficiently high level of asset tangibility given by the solution to Eq. (23), which equates the expected present value from the bank-funding rule that avoids equity issuance costs at the expense of optimal timing with the one from investing without equity issuance costs and with optimal timing, the constrained firm's problem coincides with the unconstrained firm's problem and hence contracting frictions are irrelevant in this limiting case. Intuitively, the constrained firm's bank debt coupon capacity in Eq. (21) rises with asset tangibility and hence bank debt can assume a sufficiently high value relative to the exercise cost such that $B(\widehat{X}^c) \geqslant K$ for an optimally timed exercise threshold. As a result of this larger debt capacity, the constrained firm can avoid issuing costly external equity when optimally timing option exercise and behaves like the unconstrained firm. In other words, if and only if asset tangibility is sufficiently high, then the constrained firm still implements the unconstrained firm's investment policy.

Third, Proposition 2 reveals the existence of another critical level of asset tangibility, one that solves Eq. (24). The reason for this "intermediate" region described by Eqs. (22) and (25) is that in the interval $[\underline{\tau}, \overline{\tau})$ the expected present value from investing at the non-optimally timed bank-funding threshold, which solves $B(\widehat{X}^c) - K = 0$, dominates the expected present value from investing at the optimally timed threshold with equity issuance costs.[9] At the critical level $\underline{\tau}$ (or $\overline{\tau}$) the optimally timed

[9] Intuitively, constrained firms with intermediate tangibility are willing to delay investment a bit beyond the unconstrained threshold in order to avoid equity flotation costs. These firms invest at just the bank-funding point where the bank would be willing to fund the entire investment. For constrained firms with sufficiently low tangibility, the opportunity cost (in terms of forgone dividends) of delaying investment until the bank is willing to fund the entire capital expenditure is simply too high and hence these firms act as if equity will be the marginal source of financing.

value with (or without) costly external equity financing equals the non-optimally timed value from investing at the bank-funding threshold. Importantly, the constrained firm's value-maximizing investment threshold declines with τin the interval $[\underline{\tau}, \overline{\tau})$. In other words, the constrained firm's investment problem is relaxed by asset tangibility in this region.

Finally, according to the last case in Eq. (22), the constrained firm with sufficiently low levels of asset tangibility can only exercise its option optimally by issuing a mixture of bank debt and costly external equity. For this "low tangibility" region where the firm incurs equity issuance costs, comparison of Eq. (22) to Eq. (16) implies that the ratio $\rho \equiv \widehat{X}^c/\widehat{X}^u = (1+\imath)/(1+\imath\tau)$ is strictly greater than one for non-zero equity issuance costs, increasing with equity issuance costs, and decreasing with asset tangibility. This ratio shows how tangibility also relaxes the firm's financial constraint in the "low tangibility" region where the firm incurs equity issuance costs: $\partial\rho/\partial\tau = -\imath(1+\imath)/(1+\imath\tau)^2 < 0$. Moreover, the firm's strategic behavior in the renegotiation region, $(0,\underline{X})$, leads to an endogenous "quantity constraint" that is based on its asset tangibility, τ, which, in turn, interacts with issuance costs, $\imath$. Importantly for our analysis, notice that the wedge between constrained and unconstrained investment thresholds rises with financing frictions: $\partial\rho/\partial\imath = (1-\tau)/(1+\imath\tau)^2 > 0$. Taken together, the cross-partial derivative of this wedge in the "low tangibility" region is:

$$\partial^2\rho/\partial\tau\partial\imath = -(1+\imath(2-\tau))/(1+\imath\tau)^3 < 0, \tag{26}$$

which means that the positive role of asset tangibility for investment is stronger for more constrained firms (i.e., firms with larger financing constraints benefit relatively more from asset tangibility).

In all, Proposition 2 formally characterizes how the interplay of asset tangibility, renegotiable bank debt, costly external equity, and investment gives rise to the *firm-level credit multiplier*.

2.3. Economic characterization

To see the credit multiplier at work, consider a positive innovation to investment opportunities. In particular, consider a shock to product demand (say, higher cash flows X) that implies a higher investment option value. The firm's demand for investment increases with higher potential cash flows from investment. As the firm invests, its capital base increases. If the firm's assets are intangible, an increase in the firm's asset base does not boost recovery values, which are lenders' "enforceable" outside option in case of contract renegotiations. Investment in tangible assets, in contrast, provides higher recovery values and hence a better protection from *ex post* hold-up problems (strategic default). Differently put, higher collateral values improve creditors' position in renegotiations, enlarging *ex ante* debt capacity. Access to more (or cheaper) bank credit, in turn, allows for further investment avoiding the need to tap into costly external equity. An important point brought up by the model is that this financing–investment mechanism dynamically propagates itself across time (albeit at a diminishing rate, dictated by the level of asset tangibility).

More generally, the firm-level credit multiplier effect says that greater credit capacity triggers faster investment responses to positive innovations to investment opportunities. The implication is that following a series of positive shocks to investment opportunities, constrained firms with more tangible assets will invest, on average, more often; and in a present value sense, they will invest larger amounts than otherwise identical firms with less tangible assets.

We further characterize the firm-level credit multiplier in Fig. 1 below. The figure shows the effect of asset tangibility, τ, on value-maximizing investment, where the dashed lines chart the unconstrained firm's exercise threshold, $\widehat{X}^u$, and the solid lines chart the constrained firm's exercise thresholds, $\widehat{X}^c$. It is assumed that the initial cash flow is X = \$1, the risk-free interest rate is r = 6%, the growth rate of potential cash flows is μ = 0.5%, the volatility of potential cash flows is σ = 30%, and the investment cost is K = \$10. The constrained firm in the left panel faces linear equity issuance costs of 12% whereas the more constrained firm in the right panel faces linear equity issuance costs of 12% and quadratic equity issuance costs of 1%.

Notice that the slope of the more constrained firm's exercise threshold is steeper, suggesting that the effect of asset tangibility on financing–investment dynamics is stronger for the firm that faces larger financing frictions. Simply put, as emphasized in the model solution, asset tangibility matters

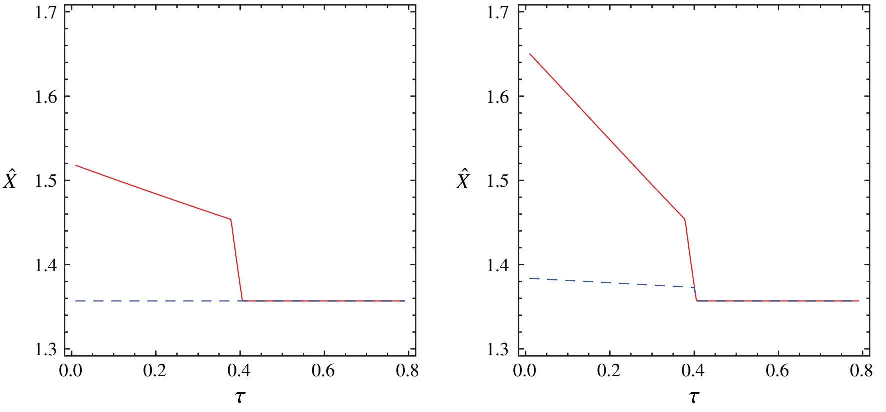

Fig. 1. Asset tangibility, financing constraints, and investment. The figure shows the effect of asset tangibility, τ, on constrained and unconstrained investment. The dashed lines chart the unconstrained firm's exercise threshold, $\widehat{X}^u$, and the solid lines plot the constrained firm's exercise thresholds, $\widehat{X}^c$. It is assumed that the initial cash flow is X = \$1, the risk-free interest rate is r = 6%, the growth rate of potential cash flows is μ = 0.5%, the volatility of potential cash flows is σ = 30%, and the investment cost is K = \$10. In the left panel, the unconstrained firm faces no equity issuance costs, while the constrained firm faces linear equity issuance costs of 12%. In the right panel, the unconstrained firm faces moderate equity issuance costs of 2%, whereas the constrained firm faces linear equity issuance costs of 12% and quadratic equity issuance costs of 1%.

relatively more for more constrained firms. Notice also that in the right panel, where the unconstrained firm faces mild financing frictions, the unconstrained investment threshold, $\widehat{X}^u$, is not completely independent of asset tangibility. Yet the unconstrained firm's response to changes in asset tangibility is much less pronounced than that of the constrained firm.

The central implication of the firm-level credit multiplier described in our model is that asset tangibility amplifies the impact of productivity shocks by reducing frictions faced by financially constrained firm. This is akin to a propagation mechanism that translates positive shocks to unobserved investment opportunities more directly into observed financing and investment when the firm faces financing frictions. These novel financing–investment interactions are dynamic in nature and create an endogenous relationship between financing and investment decisions under financing imperfections. Our analysis is in sharp contrast to those in which investment is exogenous to the firm's financial status and financing decisions.

2.4. Simulation

In addition to obtaining closed-form solutions for the constrained and the unconstrained firm values and investment strategies, our model also allows us to simulate financing–investment interactions, hence establish a closer connection between theory and empirics. Notably, we can verify our model's main empirical implication by estimating the base regression specification and the interactive (credit multiplier) specification using model-implied, simulated panel data sets.

To verify that our theoretical analysis implies a strong interaction effect between asset tangibility and Q in investment regressions (as later identified by our empirical analysis), we use simulation to generate artificial data from the model. These simulations take the solutions to the optimization problems in Propositions 1 and 2 as given and do not involve any additional optimizations. To begin, each firm i is characterized by the vector of model parameters ($Tangiblity$,K,r,X,μ,σ), which may be firm- or industry-specific. Since our focus is on the positive role of asset tangibility for constrained firms, we only need firm-level heterogeneity along this dimension. That is, *Tangibility* is specified by the set $\tau \in \{0.025, 0.05, \ldots, 0.725, 0.75\}$ scaled by K, which provides 30 different "tangibility" cases when using a step size of 0.025. The investment expenditure is normalized to K = \$10. The risk-free rate is assumed to equal r = 6%. The initial cash flow level is X_0 = \$1, the growth rate of cash flows is μ = 0.5%, and the volatility of cash flows is $\sigma = 30\%$. Finally, the firm-specific cash flow process is discretized using the following approximation for $t \geqslant \Delta t$:

$$X_t = X_{t-\Delta t} \exp\left\{ \left(\mu - \frac{1}{2}\sigma^2\right)\Delta t + \sigma\sqrt{\Delta t}\epsilon_t \right\}, \tag{27}$$

where Δt is is one quarter and ϵ_t is a standard normal random variable.

To present a realistic and rich treatment of financial constraints, we consider two alternative cases. In the first case, which corresponds to the modeling assumptions for Propositions 1 and 2, the unconstrained firm faces no equity issuance costs (i.e., $\imath = 0\%$), while in the second case the unconstrained firm faces also a mild level of floatation costs (i.e., $\imath = 2\%$). Consistent with the theoretical analysis, the constrained firm faces only a linear issuance costs of $\imath = 12\%$ in the first case. In the second case, we enrich the model simulations by letting the constrained firm face an additional quadratic floatation cost of 1%.

We want to translate the simulated X_t-paths of each firm into a time series of Q values (recall, that Q is the ratio of the firm's market value divided by its investment cost). Proposition 1 implies in case of the unconstrained firm the following $Q^u(X_t)$-paths for $X_t \leqslant \widehat{X}^u$:

$$Q^u(X_t) \equiv \frac{F^u(X_t)}{K} = \left(\frac{1}{\beta - 1}\right)^{1-\beta} \left(\frac{U\,X_t}{\beta\,K}\right)^{\beta} \qquad \forall\ \tau \in [0, 1), \tag{28}$$

which is, as suggested by economic intuition, increasing in X_t since $\beta > 1$ (i.e., $\partial Q^u/\partial X_t > 0$), but invariant to asset tangibility (i.e., $\partial Q^u/\partial\,\tau = 0$). Similarly, the theory provides analytical insights into the effect of asset tangibility on Q for constrained firms. Using the last expression from (25) in the "low tangibility" region, scaling by K, and simplifying yields for $X_t \leqslant \widehat{X}^c$:

$$Q^c(X_t) \equiv \frac{F^c(X_t)}{K} = \left(\frac{1 + \imath}{\beta - 1}\right)^{1-\beta} \left(\frac{(1 + \imath\tau)U\,X_t}{\beta\,K}\right)^{\beta} \qquad \forall\ \tau \in [0, \underline{\tau}), \tag{29}$$

which is also increasing in X_t (i.e., $\partial Q^c/\partial\,X_t > 0$).[10] In addition, growth options of constrained firms with more tangible assets are, all else equal, more valuable and hence $\partial Q^c/\partial\tau > 0$. Taken together, the firm-level credit multiplier can be re-expressed for Q: $\partial^2 Q^c/\partial\tau\partial X_t > 0$. Accordingly, the interaction term of Q and τ, $Q \times \tau$, captures the increasingly high investment propensity associated with both high cash flow levels and high tangibility levels. Note that Q alone can be high because of a rising X_t-path even when $\tau$is low, which would not imply, on average, a higher investment hazard of constrained firms. Therefore, the interaction term should measure the additional, incremental effect on investment of constrained firms when both X_t and τ are high. According to our theory, the coefficient estimate of $Q \times \tau$ should, however, be insignificant for unconstrained firms.

To minimize the influence of any particular simulation experiment, we generate in total 200 panel data sets, which are populated by 600 firms (i.e., 20 firms for each of the 30 "tangibility" cases). In each panel, we follow these firms for 70 years at a quarterly frequency. As we drop the first 35 years from each panel to minimize the influence of the initial conditions and we transform the quarterly data into annual (year-end) data, we end up with 21,000 firm-year observations per panel.

Panel A of Table 1 reports average coefficient estimates of regression results for the 200 simulated data sets with 600 firms over 35 years using the base regression specification, in which investment is modeled as a linear function of only Q and *Tangibility* (omitting at first the Q-interactive term from Eq. (31)). Panel B tabulates estimation results for the credit multiplier regression specification in Eq. (31). That is, the base investment model includes Q and *Tangbility* as firm characteristics without the Q-interactive term, while the credit multiplier (interactive) investment model contains Q, *Tangibility*, and $Q \times$ *Tangibility* as independent variables. As dependent variable, we use an investment hazard, defined as the number of investment points per firm for a given time period scaled by K. In particular, the investment intensity *Investment* = I/K is defined as the cumulative counter, $I \in \{0, 1, 2, \ldots\}$, of a firm

[10] For brevity, the value of $Q^c(X_t)$ in the "intermediate tangibility" region is suppressed and the corresponding value in the "high tangibility" region is given in Eq. (28). Naturally, all three regions are used in the simulation.

Table 1
Base and credit multiplier regressions on simulated data. This table displays (average) OLS estimation results of the base investment model (omitting the Q-interactive term from Eq. (31)) in Panel A and the credit multiplier investment model (Eq. (31) in the text) in Panel B for 200 simulated panels of 600 model firms over 35 years. The estimation results in Panels A.1 and B.1 use linear issuance costs to assign firms into "financially constrained" and "financially unconstrained" categories. The estimation results in Panels A.2 and B.2 use linear-quadratic issuance costs to assign firms into "financially constrained" and "financially unconstrained" categories. *Investment* is the ratio of the number of investment points reached by a firm over the book value of assets, K. That is, the cumulative counter of a firm starting at X and reaching an investment point, $\widehat{X}$, the first time from below and then being replaced by a replica of itself starting out again at X with the counter being moved up by one. Q is computed as firm value $F^{(\cdot)}$ divided by the book value of assets, K. *Tangibility* is specified by the set $\tau \in \{0.025, 0.05, \ldots, 0.725, 0.75\}$ scaled by K, which provides a step size of 2.5% and yields 30 "tangibility cases." In each of the 200 panels, we use 20 firms per case and hence obtain 600 firms, which we follow for 70 years at a quarterly frequency. As we drop the first 35 years from each panel and transform the quarterly data into annual (year-end) data, we end up with 21,000 firm-year observations per panel. The estimations correct the error structure for heteroskedasticity using the White estimator. Robust standard errors reported in parentheses.

Dependent variable	Independent variables			R^2	Obs.
Investment	*Q*	*Tangibility*			
Panel A: Base regressions					
A.1 Linear issuance costs					
Constrained Firms	0.1035***	0.0946***		0.16	21,000
	(0.0036)	(0.0187)			
Unconstrained Firms	0.1204***	0.0041		0.17	21,000
	(0.0040)	(0.0204)			
A.2 Linear-quadratic issuance costs					
Constrained firms	0.0970***	0.1326***		0.15	21,000
	(0.0034)	(0.0181)			
Unconstrained firms	0.1169***	0.0249		0.17	21,000
	(0.0039)	(0.0199)			
			Q × *Tangibility*		
Panel B: Credit multiplier regressions					
B.1 Linear Issuance costs					
Constrained firms	0.0764***	0.0177	0.7246***	0.16	21,000
	(0.0064)	(0.0167)	(0.1614)		
Unconstrained firms	0.1177***	−0.0022	0.0615	0.17	21,000
	(0.0081)	(0.0183)	(0.1836)		
B.2 Linear-quadratic issuance costs					
Constrained firms	0.0609***	0.0249	0.9925***	0.16	21,000
	(0.0057)	(0.0161)	(0.1528)		
Unconstrained firms	0.1087***	0.0037	0.1257	0.17	21,000
	(0.0077)	(0.0179)	(0.1782)		

Notes: **, and * indicate statistical significance at the 5%, and 10% (two-tail) test levels, respectively.
*** Statistical significance at the 1% (two-tail) test level.

starting from X and reaching an investment point, $\widehat{X}$, the first time from below divided by the book value of assets, K. At the time of reaching an investment point, the firm is replaced by a replica of itself starting again at the initial cash flow level with an identical but unexercised option.

To begin, for each of the two cases of financial constraints considered in Panel A of Table 1, we observe that *Investment* responds very significantly to Q across all estimations and partitions. As expected from the real options model, Q is particularly strong across financially constrained firms. Interestingly, *Investment* only responds reliably to *Tangiblity* for constrained firms in the model-implied, simulated panel data sets.

As discussed above, a direct way to gauge the multiplier effect in the actual and simulated data is to interact Q with *Tangibility*. Panel B tests the main prediction of our model by estimating Eq. (31) across subsamples of constrained and unconstrained firms in the artificial data. Consistent with the economic intuition derived from the model, we can generally reject with high statistical confidence (lower than 1% test-level) the hypothesis that the coefficients on the interaction term are similar across subsamples of constrained and unconstrained model firms. Moreover, the table reinforces the existence of an important interactive (multiplier) effect of *Q* and *Tangibility* across financially constrained firms. Simply put, the tangibility-led firm-level credit multiplier disappears in the absence of model-induced financing constraints. However, it plays an increasingly important role in explaining investment intensities as model-induced financing constraints increase. As will be made clearer in Section 4, Table 1 implies a notable success in linking the model-implied regression results for artificial data to the regression results we obtain using COMPUSTAT data.

3. Data and empirical test design

3.1. Data description

Our sample selection approach follows that of Almeida et al. (2004) and Almeida and Campello (2007). We consider the universe of U.S. manufacturing firms (SICs 2000–3999) over the 1971–2005 period with data available from COMPUSTAT on total assets, market capitalization, capital expenditures, and plant property and equipment (capital stock). We eliminate firm-years for which the value of capital stock is less than $1 million, those displaying real asset or sales growth exceeding 100%, and those with negative *Q* or with *Q* in excess of 10 (we define *Q* shortly). The first selection rule eliminates very small firms from the sample, for which linear investment models are likely inadequate (see Gilchrist and Himmelberg, 1995). The second data cut-off eliminates those firm-years registering large jumps in their business fundamentals (size and sales); these are typically indicative of mergers, reorganizations, and other major corporate events. The third cut-off is introduced as a first, crude attempt to minimize the impact of problems in the measurement of investment opportunities, and to improve the fitness of our investment demand model. Among many others, Abel and Eberly (2002) and Cummins et al. (2006) use similar cut-offs and discuss the poor empirical fit of linear investment equations at high levels of *Q*. We deflate all series to 1971 dollars using the CPI.

Our basic sample consists of an unbalanced panel with 65,508 firm-year observations with 6,316 unique firms. Table 2 describes the computation and reports summary statistics for the variables used in our main tests. Since our sampling and variable construction methods follow that of the literature, it is not surprising that the numbers we report in Table 2 resemble those found in related studies (e.g., Almeida and Campello, 2007). In the interest of brevity, we omit a detailed discussion of the sample summary statistics.

3.2. Empirical specification

The central result of our theory is that of a feedback effect between investment and financing in the presence of credit constraints: tangible assets ease financing, which amplifies the response of firm

Table 2
Sample descriptive statistics. This table displays summary statistics for the main variables used in the empirical estimations. All firm data are collected from COMPUSTAT's annual industrial tapes over the 1971–2005 period. The sample firms are from manufacturing industries (SICs 2000–3999). *Assets* is the firm's total assets (COMSPUSTAT's item #6), expressed in millions of CPI-adjusted 1971 dollars. *Investment* is the ratio of fixed capital expenditures (item #128) over lagged fixed capital stock (item #8). *Q* is computed as the market value of assets divided by the book value of assets, or (item #6 + (item #24 × item #25) − item #60 − item #74)/(item #6). *Tangibility* is the expected value of assets in liquidation (the computation follows Berger et al. (1996)). *Leverage* is computed as item #9 divided by item #6. *DebtIssuance* is the change in long- (Δitem #9) and short-term debt (Δitem #34) over lagged total assets.

Variables	Statistics					
	Mean	Median	Std. Dev.	25th Pct.	75th Pct.	Obs.
Assets	155.6	14.1	690.2	4.3	60.8	65,107
Investment	0.2617	0.1884	0.2584	0.1159	0.3088	58,633
Q	0.8733	0.7695	0.5196	0.6355	0.9494	65,107
Tangibility	0.5583	0.5648	0.1196	0.5035	0.6118	64,788
Leverage	0.1713	0.1404	0.1655	0.0377	0.2573	64,788
DebtIssuance	0.0015	−0.0079	0.1449	−0.0485	0.0242	57,087

investment spending to shifts in firm investment opportunities. We develop two empirical models to test our credit multiplier idea, one concerns investment, the other concerns financing decisions.

First, we specify a multiplicative-type model relating investment spending (I) to investment opportunities (Q) and asset tangibility (τ). In particular, we consider:

$$i_t = \alpha_1 Q_{t-1} + \alpha_2 \tau_{t-1} + \alpha_3 (Q_{t-1} \times \tau_{t-1}), \tag{30}$$

where $i_t = I_t/K_{t-1}$ denotes capital-normalized investment over time t. Our credit multiplier theory predicts that the interaction term $Q \times \tau$ has a *positive* coefficient in an investment equation like Eq. (30) when the firm faces financing constraints; in short, the firm invests relatively more in response to positive investment opportunities when its assets allow for more credit capacity. No such effects should be observed in a cross-section of financially unconstrained firms.

To operationalize our test, we experiment with a parsimonious model of investment demand. We do so by augmenting the standard Q-theory investment equation with a proxy for asset tangibility and an interaction term that allows the role of Q to vary with asset tangibility. Define *Investment* as the ratio of capital expenditures (COMPUSTAT item #128) to beginning-of-period capital stock (lagged item #8). Q is our basic proxy for investment opportunities, computed as the market value of assets divided by the book value of assets, or (item #6 + (item #24 × item #25) – item #60 – item #74)/(item #6). We define *Tangibility* shortly (see Section 3.3). Our first empirical model can be written as follows:

$$Investment_{i,t} = \alpha_1 Q_{i,t-1} + \alpha_2 Tangibility_{i,t-1} + \alpha_3 (Q \times Tangibility)_{i,t-1} + \sum_i Firm_i + \sum_t Year_t + \varepsilon_{i,t}, \tag{31}$$

where *Firm* and *Year* capture firm- and year-specific effects, respectively. All of our estimations correct the regression error structure for within-firm correlation (firm clustering) and heteroskedasticity using White-Huber's error-consistent estimator. Reported R^2s account for fixed effects.

It is worth noting that a large literature includes a firm's cash flow in investment regressions such as Eq. (31). Our model does not generate explicit predictions for firm cash flows, but in the robustness checks that follow we also include cash flows in our model specifications. This allows for comparisons with previous studies and serves the purpose of checking whether our findings could be explained by income shocks (see Section 4.1.3).

Secondly, we study a model of external financing. Define *DebtIssuance* as the change in the ratio of short- and long-term debt (item #9 + item #34) to lagged book value of assets (item #6). We regress this measure of debt taking on Q, *Tangibility*, and an interaction term that allows the role of Q to vary with *Tangibility*. Our second empirical model can be expressed as:

$$DebtIssuance_{i,t} = \alpha_1 Q_{i,t-1} + \alpha_2 Tangibility_{i,t-1} + \alpha_3 (Q \times Tangibility)_{i,t-1} + \sum_i Firm_i + \sum_t Year_t + \varepsilon_{i,t}. \tag{32}$$

Following the standard literature, we allow the coefficient vector $\boldsymbol{\alpha}$ in Eqs. (31) and (32) to vary with the degree to which the firm faces financing constraints by way of fitting our models separately across samples of constrained and unconstrained firms. In contrast to much of the literature, we also estimate $\boldsymbol{\alpha}$ using a maximum likelihood methodology in which constraint assignments are determined jointly with the investment (or debt taking) process (see Section 3.4).

According to our theory, the extent to which investment opportunities matters for constrained investment (alternatively, debt taking) should be an increasing function of asset tangibility. While Eq. (31) (Eq. (32)) is a direct linear measure of the influence of tangibility on investment (debt) sensitivities, note that its interactive form makes the interpretation of the estimated coefficients less obvious. For instance, if one wants to assess the partial effect of Q on *Investment* (*DebtIssuance*), one has to read off the result from $\alpha_1 + \alpha_3 \times$ *Tangibility*. Hence, in contrast to other papers in the literature, the estimate returned for α_1 alone says little about the impact of Q on investment demand (debt taking). That coefficient represents the impact of Q when *Tangibility* equals zero, a point that lies outside of the empirical distribution of our measures of asset tangibility. As we discuss below, the summary statistics of Table 2 will aid in the interpretation of the estimates returned by our interactive model.

3.3. Proxy for asset tangibility

We proxy for asset tangibility (*Tangibility*) using a firm-level measure of expected asset liquidation values that borrows from Berger et al. (1996). In determining whether investors rationally value their firms' abandonment option, Berger et al. gather data on the proceeds from discontinued operations reported by a sample of manufacturing firms over the 1984–1993 period. The authors find that a dollar of book value yields, on average, 72 cents in exit value for total receivables, 55 cents for inventory, and 54 cents for fixed assets. Following their study, we estimate liquidation values for the firm-years in our sample via the computation:

$$Tangibility = 0.715 \times Receivables + 0.547 \times Inventory + 0.535 \times Capital,$$

where *Receivables* is COMPUSTAT item #2, *Inventory* is item #3, and *Capital* is item #8. As in Berger et al., we add the value of cash holdings (item #1) to this measure and scale the result by total book assets.

3.4. Financially constrained and financially unconstrained groupings

Our tests require splitting firms according to measures of financing constraints. There are many plausible approaches to sorting firms into financially "constrained" and "unconstrained" categories. Our basic approach follows the standard literature, using *ex-ante* financial constraint sortings that are based on firm observables, such as payout policy, firm size, and debt ratings. In particular, we adopt the sorting schemes discussed in Almeida et al. (2004) and Acharya et al. (2007):

- Scheme #1: In every year over the 1971–2005 period, we rank firms based on their payout ratio and assign to the financially constrained (unconstrained) category those firms in the bottom (top) three deciles of the payout distribution. We compute the payout ratio as the ratio of total distributions (dividends plus stock repurchases) to assets. The intuition that financially constrained firms have lower payout follows from the argument that their reluctance to distribute funds is caused by a wedge between the costs of internal and external financing.
- Scheme #2: We rank firms based on their total assets throughout the 1971–2005 period and assign to the financially constrained (unconstrained) category those firms in the bottom (top) three deciles of the asset size distribution. The rankings are again performed on an annual basis. The argument for size as a good measure of financing constraints is that small firms are typically young and less well known and thus more likely to face capital market frictions.
- Scheme #3: We retrieve data on firms' bond ratings and categorize those firms that never had their public debt rated during our sample period as financially constrained. Given that unconstrained firms may choose not to use debt financing (thus not receiving a debt rating), we only assign to the constrained subsample those firm-years that *both* lack a rating and report positive debt (see Faulkender and Petersen, 2006).[11] Financially unconstrained firms are those whose bonds have been rated during the sample period. The advantage of this measure of constraints over the former two is that it gauges the *market*'s assessment of a firm's credit quality. The same rationale applies to the next measure.
- Scheme #4: We retrieve data on firms' commercial paper ratings and categorize as financially constrained those firms that never display any ratings during our sample period. Observations from those firms are only assigned to the constrained subsample in years in which positive debt is reported. Firms that issued rated commercial paper at some point during the sample period are considered unconstrained.

[11] Firms with no bond ratings and no debt are not considered constrained, but our results are unaffected by how we treat these firms. The same approach is used for firms with no commercial paper ratings and no debt in Scheme #4.

Table 3
Cross-classification of financial constraint types. This table displays firm-year cross-classifications for the various criteria used to categorize firms as either financially constrained or unconstrained (see text for definitions). To ease visualization, we assign the letter (C) for constrained firms and (U) for unconstrained firms in each row/column. All firm data are collected from COMPUSTAT's annual industrial tapes over the 1971–2005 period. The sample firms are from manufacturing industries (SICs 2000–3999).

Financial constraints criteria		Div. payout		Firm size		Bond ratings		CP ratings	
		(C)	(U)	(C)	(U)	(C)	(U)	(C)	(U)
1. Payout policy									
Constrained firms	(C)	27,658							
Unconstrained firms	(U)		19,549						
2. Firm size									
Constrained firms	(C)	12,857	2,750	19,550					
Unconstrained firms	(U)	3689	9849		19,549				
3. Bond ratings									
Constrained firms	(C)	23,723	14,786	19,108	11,391	52,915			
Unconstrained firms	(U)	3935	4763	442	8158		12,192		
4. Comm. paper ratings									
Constrained firms	(C)	26,964	16,896	19,533	15,106	52,822	7571	60,393	
Unconstrained firms	(U)	694	2653	17	4443	93	4621		4714

Table 3 reports the number of firm-years under each of the financial constraint categories used in our analysis. According to the payout scheme, for example, there are 27,658 financially constrained firm-years and 19,549 financially unconstrained firm-years. The table also shows the extent to which the four classification schemes are related. For example, out of the 27,658 firm-years classified as constrained according to the payout scheme, 12,857 are also constrained according to the size scheme, while a much smaller fraction, 3689 firm-years, are classified as unconstrained. The remaining firm-years represent payout-constrained firms that are neither constrained nor unconstrained according to size. In general, there is a positive association among the four measures of financing constraints. For example, most small (large) firms lack (have) bond ratings. Also, most small (large) firms make low (high) payouts. However, the table also makes it clear that these cross-group correlations are far from perfect. This works against our tests finding consistent results across all classification schemes.

One potential drawback of the *ex-ante* sorting approach described above is that it does not allow the investment process to work as a determinant of the financial constraint status — the constraint categorization is exogenously given. In turn, we consider an alternative categorization approach that endogenizes the constraint status together with other variables in a structural model. The approach, borrowed from Hovakimian and Titman (2006), uses a switching regression framework with unknown sample separation to estimate investment regressions. One advantage of this estimator is that we can simultaneously use all of the above sorting information (i.e., dividend policy, size, bond ratings, and commercial paper ratings) together with asset tangibility to categorize firms. In turn, we provide a brief summary of this methodology.

Assume that there are two different investment regimes, which we denote by "regime 1" and "regime 2." While the number of investment regimes is given, the points of structural change are not observable and are estimated together with the investment equations. The model is composed of the following system of equations (estimated simultaneously):

$$I_{1it} = \mathbf{X}_{it}\alpha_1 + \varepsilon_{1it} \tag{33}$$

$$I_{2it} = \mathbf{X}_{it}\alpha_2 + \varepsilon_{2it} \tag{34}$$

$$y^*_{it} = \mathbf{Z}_{it}\phi + u_{it}. \tag{35}$$

Eqs. (33) and (34) are the structural equations of the system; they are essentially two versions of our baseline investment model in Eq. (31). Let $\mathbf{X}_{it}$ be the vector of explanatory variables, and $\boldsymbol{\alpha}$ be the vector of coefficients that relates the variables in $\mathbf{X}$ to investment I_{1it} and I_{2it}. Differential investment behavior across firms in regime 1 and regime 2 is captured by differences between α_1 and α_2. Eq. (35) is the selection equation that establishes the firm's likelihood of being in regime 1 or regime 2.

The vector $\mathbf{Z}_{it}$ contains the determinants of a firm's propensity of being in either regime. Observed investment is given by:

$$I_{it} = I_{1it} \text{ if } y^*_{it} < 0$$
$$I_{it} = I_{2it} \text{ if } y^*_{it} \geqslant 0. \quad (36)$$

y^*_{it} is a latent variable that gauges the likelihood that the firm is in the first or in the second regime.

The parameters α_1, α_2, and $\phi$are estimated via maximum likelihood. To estimate those parameters, we assume that the error terms ε_1, ε_2, and u are jointly normally distributed. Critically, the estimator's covariance matrix allows for non-zero correlation between shocks to investment and shocks to firms' characteristics — this makes the model we use an 'endogenous switching regression.' As such, the extent to which investment spending differs across the two regimes and the likelihood that firms are assigned to either regime are *simultaneously* determined.

Finally, to identify the system we need to determine which regime is the constrained one and which regime is the unconstrained one. The algorithm in Eqs. (33)–(36) creates two groups of firms that differ according to their investment behavior, but it does not tell the econometrician which firms are constrained. To achieve identification, we need to use priors about which firm characteristics that are likely to be associated with financing constraints. We do so using the same characteristics employed in the *ex-ante* sortings (payout, size, and ratings). We also include *Tangibility*, since as described by our model, asset tangibility can ameliorate financing constraints.

4. Empirical results

Our tests first consider corporate investment. We subsequently examine cross-sectional patterns in firm financing (debt capacity and debt issuance).

4.1. Tests on investment spending

Our examination of corporate investment considers a standard investment equation and an interactive ("multiplier") model. We then perform robustness checks that help rule out alternative explanations for our findings.

4.1.1. The base investment model

We build intuition for our study's empirical tests by way of estimating a simpler version of Eq. (31). In this version, corporate investment is modeled as a linear function of only *Q* and *Tangibility*. We would expect both of these variables to retain some explanatory power over the cross-sectional variation of investment. In particular, absent empirical biases, investment spending should respond to proxies for investment opportunities across all sets of firms (both financially constrained and unconstrained firms). As for asset tangibility, we would expect it to be a strong determinant of investment across financially constrained firms, carrying less importance (if any) in the cross-section of financially unconstrained firms.

Table 4 reports estimation results for the base regression model across financially constrained and unconstrained firm partitions. Panel A collects results based on exogenous characterizations of constraints, while Panel B considers the endogenous regime switching approach. For each of the ten constrained/unconstrained comparison pairs in Table 4, we observe that *Investment*responds very significantly to *Q* across all estimations and partitions. Interestingly, the coefficient for *Q* is particularly strong across financially constrained firms. This is noteworthy because much of the debate about empirical biases in investment regressions in the last decade revolved around an attenuation bias that appeared to affect constrained firms' *Q* in a pronounced fashion. Like other recent studies (e.g., Baker et al., 2003; Campello and Graham, forthcoming), we find no indication that attenuation bias in *Q* disproportionately affects financially constrained firms' investment regressions.

Also noteworthy is the response of *Investment* to *Tangibility*. Consistent with the basic logic of our theory, asset tangibility is systematically, positively associated with investment spending when firms are financially constrained. Indeed, our estimates suggest that this relation is economically strong. For

Table 4
Investment spending, *Q*, and asset tangibility: base regressions. This table displays OLS-FE (firm- and year-fixed effects) estimation results of the base investment model (omitting the *Q*-interactive term from Eq. (31) in the text). The estimations in Panel A use pre-determined firm selection into "financially constrained" and "financially unconstrained" categories. Constraint category assignments use ex-ante criteria based on firm dividend payout, asset size, bond ratings, and commercial paper ratings. In Panel B, switching regression estimations allow for endogenous selection into "financially constrained" and "financially unconstrained" categories via maximum likelihood methods. The "regime selection" regression (unreported) uses payout ratio, asset size, a dummy for bond ratings, a dummy for commercial paper ratings, and *Tangibility* as selection variables to classify firms into constraint categories (see text for details). *Investment* is the ratio of fixed capital expenditures (item #128) over lagged fixed capital stock (item #8). *Q* is computed as the market value of assets divided by the book value of assets, or (item #6 + (item #24 × item #25) – item #60 – item #74)/(item #6). *Tangibility* is an annual, firm-level proxy for expected value of assets in liquidation (the computation follows Berger et al. (1996)). All firm data are collected from COMPUSTAT's annual industrial tapes over the 1971–2005 period. The sample firms are from manufacturing industries (SICs 2000–3999). The estimations correct the error structure for heteroskedasticity and clustering using the White-Huber estimator. Robust standard errors reported in parentheses.

Dependent variable	Independent variables		R^2	Obs.
Investment	*Q*	*Tangibility*		
Panel A: Exogenous financial constraint categorizations (ex-ante classifications)				
1. Payout policy				
Constrained firms	0.1284***	0.5605***	0.07	22,512
	(0.0088)	(0.0328)		
Unconstrained firms	0.0605***	0.0891*	0.02	17,915
	(0.0065)	(0.0458)		
2. Firm size				
Constrained firms	0.1090***	0.6491***	0.06	17,259
	(0.0104)	(0.0455)		
Unconstrained firms	0.0663***	0.1557***	0.05	17,949
	(0.0073)	(0.0235)		
3. Bond ratings				
Constrained firms	0.0940***	0.4251***	0.05	45,226
	(0.0056)	(0.0252)		
Unconstrained firms	0.0804***	0.0787**	0.03	11,051
	(0.0104)	(0.0321)		
4. Comm. paper ratings				
Constrained firms	0.0939***	0.3978**	0.05	51,893
	(0.0055)	(0.0229)		
Unconstrained firms	0.0780***	0.0857	0.06	4384
	(0.0097)	(0.0574)		
Panel B: Endogenous financial constraint categorizations (switching regressions)				
Constrained firms	0.0708***	0.2906***	0.05	56,252
	(0.0039)	(0.0153)		
Unconstrained firms	0.0842***	0.1315	0.02	56,252
	(0.0150)	(0.1376)		

* Statistical significance at the 10% (two-tail) test level.
** Statistical significance at the 5% (two-tail) test level.
*** Statistical significance at the 1% (two-tail) test level.

example, the estimates from the first partition reported in Table 4 (see row 1 in Panel A) imply that a one-standard deviation increase in *Tangibility* leads to an increase of 6.7%(=0.5605 × 0.1196) in *Investment*, an increase that is equivalent to 25.6% (=0.0670/0.2617) of the average investment rate of our sample. These pronounced effects are not observed across financially unconstrained firms. For those firms, the coefficients returned for *Tangibility* are significantly lower than those returned for constrained firms.

4.1.2. The credit multiplier effect

Our model's central insight is related to the amplifying effect of asset tangibility on the response of investment spending to investment opportunities in the presence of financing constraints — the credit multiplier. As previously discussed, a direct way to gauge the multiplier effect in the data is to interact

Table 5
Investment spending, Q, and asset tangibility: the credit multiplier effect. This table displays OLS-FE (firm- and year-fixed effects) estimation results of the credit multiplier investment model (Eq. (31) in the text). The estimations in Panel A use pre-determined firm selection into "financially constrained" and "financially unconstrained" categories. Constraint category assignments use ex-ante criteria based on firm dividend payout, asset size, bond ratings, and commercial paper ratings. In Panel B, switching regression estimations allow for endogenous selection into "financially constrained" and "financially unconstrained" categories via maximum likelihood methods. The"regime selection" regression (unreported) uses payout ratio, asset size, a dummy for bond ratings, a dummy for commercial paper ratings, and *Tangibility* as selection variables to classify firms into constraint categories (see text for details). *Investment* is the ratio of fixed capital expenditures (item #128) over lagged fixed capital stock (item #8). Q is computed as the market value of assets divided by the book value of assets, or (item #6 + (item #24 × item #25) − item #60 − item #74)/(item #6). *Tangibility* is an annual, firm-level proxy for expected value of assets in liquidation (the computation follows Berger et al. (1996)). All firm data are collected from COMPUSTAT's annual industrial tapes over the 1971–2005 period. The sample firms are from manufacturing industries (SICs 2000–3999). The estimations correct the error structure for heteroskedasticity and clustering using the White-Huber estimator. Robust standard errors reported in parentheses.

Dependent variable	Independent variables			R^2	Obs.
Investment	*Q*	*Tangibility*	*Q* × *Tangibility*		
Panel A: Exogenous financial constraint categorizations (ex-ante classifications)					
Financial constraints criteria					
1. Payout policy					
Constrained firms	0.0285	0.4214***	0.1571***	0.07	22,512
	(0.0310)	(0.0525)	(0.0505)		
Unconstrained firms	0.1139***	0.1656***	−0.0884*	0.02	17,915
	(0.0312)	(0.0510)	(0.0524)		
2. Firm size					
Constrained firms	0.0165	0.5264***	0.1421**	0.07	17,259
	(0.0423)	(0.0693)	(0.0692)		
Unconstrained firms	0.1311***	0.2572***	−0.1099**	0.05	17,949
	(0.0290)	(0.0521)	(0.0526)		
3. Bond ratings					
Constrained firms	0.0196	0.3239***	0.1177***	0.05	45,226
	(0.0244)	(0.0400)	(0.0408)		
Unconstrained firms	0.1357***	0.2664***	−0.0962	0.03	11,051
	(0.0486)	(0.0844)	(0.0869)		
4. Comm. paper ratings					
Constrained firms	0.0247	0.3026***	0.1101***	0.05	51,893
	(0.0236)	(0.0382)	(0.0393)		
Unconstrained firms	0.1691***	0.2377***	−0.1596**	0.06	4384
	(0.0470)	(0.0743)	(0.0786)		
Panel B: Endogenous financial constraint categorizations (switching regressions)					
Constrained firms	0.1723*	0.1965	0.3996***	0.04	56,252
	(0.0911)	(0.1865)	(0.1339)		
Unconstrained firms	0.0308*	0.2305***	0.0601	0.05	56,252
	(0.0171)	(0.0267)	(0.0393)		

* Statistical significance at the 10% (two-tail) test level.
** Statistical significance at the 5% (two-tail) test level.
*** Statistical significance at the 1% (two-tail) test level.

Q with *Tangibility*. We now perform several tests of the main prediction of our model, estimating Eq. (31) across various subsamples.

Our main empirical findings are reported in Table 5, which has the same layout of Table 4. The results presented are remarkably strong: for every single comparison pair, the interaction term of Q and *Tangibility* is highly significant and positive for constrained firms, while either negative or indistinguishable from zero for unconstrained firms. Indeed, one can generally reject with high statistical confidence (lower than 1% test-level) the hypothesis that the coefficients of interest are similar across the two constraint types. Noteworthy, the table reveals not only the existence of an important interactive (multiplier) effect of *Tangibility* across financially constrained firms, but also that much of the unconditional impact of Q on *Investment* for constrained firms (as reported in Table 4) is transmitted via *Tangibility*. Simply put, the direct effect of *Q* on *Investment* across constrained firms, though still positive, dwarfs in comparison with the effect that comes via its interaction with *Tangibility*.

To illustrate the economic importance of the estimates in Table 5, consider again the one reported in the first row of Panel A. While *Q* alone (i.e., uninteracted) has only a small effect on investment, a one-standard deviation change in *Q*(=0.5196), measured at the average level of *Tangibility*(=0.5583), leads to a 6.0%(=0.0148 + 0.0456) increase in *Investment* (approximately 23.1% of the average sample rate of investment).

The evidence uncovered in Table 5 is remarkably consistent with the credit multiplier. They show that, in the presence of financing frictions, investment spending responds more strongly to the arrival of new investment opportunities when a firm's assets provide more valuable collateral.

4.1.3. Robustness of the multiplier effect

This section collects a battery of tests designed to verify the robustness of our central findings. Among other things, we experiment with additional estimation procedures, consider the issue of mismeasurement in *Q*, and include firm cash flows in our specifications. To save space, we only report results based on standard measures of financial constraints.

4.1.3.1. GMM estimations. OLS estimations of investment models are believed to suffer from a number of empirical biases. As such, one could wonder about the robustness of our main results relative to estimation approaches that ameliorate issues such as endogeneity and heteroskedasticity. To assess whether our findings are sensitive to the estimation methodology used, we re-estimate the models of Table 5 via GMM. We do so following Cummins et al. (2006) and use up to three lags of the variables included in Eq. (31) in our set of instruments. While those included regressors are in *level* form, our instruments are in *differenced* form.

We find that these standard GMM estimations return coefficients that are both economically and statistically more significant than those from the OLS model. Importantly, the inferences that we obtain are similar. Once again, *Tangibility* significantly strengthens the effect of *Q* on *Investment* for financially constrained firms, but not for unconstrained firms. We omit the tabulation of these GMM estimations to save space.

4.1.3.2. Mismeasurement in the proxy for investment opportunities. Prior work on investment estimations has cited concerns with the possibility that the standard proxy for investment opportunities, *Q*, could suffer from pronounced mismeasurement (e.g., Cummins et al., 2006). One problem with mismeasurement is that it introduces a downward bias in the variable affected by it. In our application, the possibility that *Q* is severely mismeasured would lead the OLS estimator to over-reject the hypothesis that *Q* is different from zero. As we have shown in our base tests, however, *Q* is statistically significant in *all* of the regressions in which it is not further interacted with *Tangibility*. When we interact *Q* with *Tangibility*, *Q* still remains the main driver of investment, only now via the interaction term.

It is not easy to determine how an attenuation bias in *Q* could systematically explain our findings. For instance, the impact of that bias on other estimates would depend on the covariance between *Q* and *Tangibility*. As it turns out, we find that such covariance is insignificant for our measures of tangibility. Nevertheless, we note that the existing literature proposes remedies for mismeasurement in *Q* that are easy to implement. Cummins et al. (2006), for example, contend that *Q* is likely to capture the firm's investment opportunities with error because equity market values (in the numerator of *Q*) often deviate from firm fundamentals, thereby misrepresenting the firm's marginal product of investment. Those papers propose, instead, a proxy for *Q* (called *RealQ*) that is derived from earnings projections made by financial analysts. The empirical implementation of *RealQ* mimics exactly that of standard *Q*, except that one proxies for the unobserved future marginal products of capital with an approximation for the future average products based on long-term earnings forecasts from IBES. Studies using *RealQ* show that it systematically outperforms standard *Q* in empirical investment regressions. A limitation of this approach, however, is that only a relatively small subset of firms in COMPUSTAT has long-term earnings forecasts reported in IBES. Additionally, note that IBES only consistently reports earnings forecasts starting in 1989. These data considerations reduce the sample used in our *RealQ* tests.

Table 6
Investment spending, Q, and asset tangibility: the credit multiplier effect replacing Q with *RealQ*. This table displays OLS-FE (firm- and year-fixed effects) estimation results of the credit multiplier investment model (Eq. (31) in the text), where conventional Q is replaced by Cummins et al.'s (2006) measurement-robust *RealQ* (based on long-term earning forecasts from IBES). The estimations use pre-determined firm selection into "financially constrained" and "financially unconstrained" categories. Constraint category assignments use ex-ante criteria based on firm dividend payout, asset size, bond ratings, and commercial paper ratings (see text for details). *Investment* is the ratio of fixed capital expenditures (item #128) over lagged fixed capital stock (item #8). *Tangibility* is an annual, firm-level proxy for expected value of assets in liquidation (the computation follows Berger et al. (1996)). All firm data are collected from COMPUSTAT's annual industrial tapes. The sample firms are from manufacturing industries (SICs 2000–3999). The estimations correct the error structure for heteroskedasticity and clustering using the White-Huber estimator. Robust standard errors reported in parentheses.

Dependent variable	Independent variables			R^2	Obs.
Investment	*RealQ*	*Tangibility*	*RealQ* × *Tangibility*		
Financial constraints criteria					
1. Payout policy					
Constrained firms	−0.0798	0.4653***	0.1757***	0.04	2271
	(0.0587)	(0.0953)	(0.0547)		
Unconstrained firms	0.1153**	0.1199**	−0.0479	0.03	3162
	(0.0573)	(0.0589)	(0.0965)		
2. Firm size					
Constrained firms	0.0314	0.6304***	0.1343***	0.03	578
	(0.0783)	(0.1840)	(0.0437)		
Unconstrained firms	0.0017	0.1585***	−0.1294	0.03	3611
	(0.0622)	(0.0613)	(0.1000)		
3. Bond ratings					
Constrained firms	0.0255	0.2837***	0.1343**	0.03	5307
	(0.0525)	(0.0667)	(0.0618)		
Unconstrained firms	0.0068	0.2519***	−0.0568	0.02	1673
	(0.0663)	(0.0741)	(0.1168)		
4. Comm. paper ratings					
Constrained firms	−0.0169	0.2856***	0.1191***	0.03	6161
	(0.0489)	(0.0608)	(0.0366)		
Unconstrained firms	0.0104	0.1848***	0.0503	0.03	819
	(0.0486)	(0.0702)	(0.1006)		

Notes: * indicate statistical significance at the 10% (two-tail) test level.
** Statistical significance at the 5% (two-tail) test level.
*** Statistical significance at the 1% (two-tail) test level.

In Table 6, we re-estimate the models of Table 5 (Panel A) replacing Q with *RealQ*. We again find strong support for our theory's main prediction: *Tangibility* reliably amplifies the impact of Q (i.e., *RealQ*) on *Investment* for financially constrained firms, but not for unconstrained firms.

4.1.3.3. Including cash flows in the benchmark model. The original Q theory of investment does not prescribe a role for cash flows as a driver of investment. Since the work of Fazzari et al. (1988), however, it has become common practice to include cash flows in empirical investment equations as a way to gauge the impact of financing constraints on investment decisions. Noteworthy, Fazzari et al.'s proposed interpretation of investment-cash flow sensitivities has been criticized on theoretical grounds (e.g., Kaplan and Zingales, 1997) as well as on grounds that empirical biases may plague estimates of that sensitivity (Gomes, 2001; Cummins et al., 2006). In addition to these limitations, we note that our theory does not have explicit predictions for the role of cash flows. As result, we chose to omit cash flows from our benchmark regression model. Nevertheless, it might be worth it experimenting with the inclusion of firm cash flows in our estimations. Doing so will allow for comparisons with previous studies and also serve the purpose of checking whether our findings could be explained by stories based on the response of investment to income shocks.

In Table 7, we estimate models similar to those of Table 5 (Panel A), but now including lagged *CashFlow* (COMPUSTAT item #18 plus item #14, scaled by lagged item #8) as an additional control. Consistent with prior studies, our estimations suggest that constrained firms' investment is positively

Table 7
Investment spending, Q, and asset tangibility: the credit multiplier effect including *CashFlow*. This table displays OLS-FE (firm- and year-fixed effects) estimation results of the credit multiplier investment model (Eq. (31) in the text), with the inclusion of cash flow as a control variable. The estimations use pre-determined firm selection into "financially constrained" and "financially unconstrained" categories. Constraint category assignments use ex-ante criteria based on firm dividend payout, asset size, bond ratings, and commercial paper ratings (see text for details). *Investment* is the ratio of fixed capital expenditures (item #128) over lagged fixed capital stock (item #8). Q is computed as the market value of assets divided by the book value of assets, or (item #6 + (item #24 × item #25) – item #60 – item #74)/(item #6). *CashFlow* is the ratio of operating income (item #18 + item #14) over lagged fixed capital stock. *Tangibility* is an annual, firm-level proxy for expected value of assets in liquidation (the computation follows Berger et al. (1996)). All firm data are collected from COMPUSTAT's annual industrial tapes over the 1971–2005 period. The sample firms are from manufacturing industries (SICs 2000–3999). The estimations correct the error structure for heteroskedasticity and clustering using the White-Huber estimator. Robust standard errors reported in parentheses.

Dependent variable	Independent variables				R^2	Obs.
Investment	*Q*	*CashFlow*	*Tangibility*	*Q* × *Tangibility*		
Financial constraints criteria						
1. Payout policy						
Constrained firms	0.0126	0.0011**	0.3265***	0.1787***	0.07	19,956
	(0.0322)	(0.0005)	(0.0545)	(0.0540)		
Unconstrained firms	0.1097***	0.0006	0.1626***	−0.0795	0.02	17,103
	(0.0363)	(0.0014)	(0.0569)	(0.0608)		
2. Firm size						
Constrained firms	0.0082	0.0099*	0.4032***	0.1416**	0.05	13,141
	(0.0449)	(0.0060)	(0.0705)	(0.0748)		
Unconstrained firms	0.1419***	0.0020	0.2671***	−0.1233**	0.05	17,105
	(0.0268)	(0.0024)	(0.0477)	(0.0473)		
3. Bond ratings						
Constrained firms	0.0334	0.0016*	0.2899***	0.0902**	0.05	41,230
	(0.0256)	(0.0009)	(0.0410)	(0.0431)		
Unconstrained firms	0.1011*	0.0004	0.1881**	−0.0241	0.03	10,506
	(0.0542)	(0.0004)	(0.0844)	(0.0979)		
4. Comm. paper ratings						
Constrained firms	0.0365	0.0017*	0.2695***	0.0867**	0.04	47,522
	(0.0245)	(0.0010)	(0.0394)	(0.0416)		
Unconstrained firms	0.1674***	0.0005	0.2311***	−0.1485*	0.06	4214
	(0.0478)	(0.0007)	(0.0728)	(0.0789)		

* Statistical significance at the 10% (two-tail) test level.
** Statistical significance at the 5% (two-tail) test level.
*** Statistical significance at the 1% (two-tail) test level.

affected by cash flows; however, their investment-cash flow sensitivities are only marginally statistically significant (at the 10 to 5% test level). The salient feature of this new round of estimations is that our inferences about the credit multiplier effect remain unchanged. In particular, the new estimates for the Q × *Tangibility* term closely resemble those of our benchmark regressions, but with a slight loss in statistical significance.

4.1.3.4. Further checks. We further examine the robustness of our results by way of changing our proxy for asset tangibility and by considering time-varying industry effects in our estimations.

Following Kessides (1990) and Worthington (1995), we also measure asset redeployability using the ratio of used to total (used plus new) fixed depreciable capital expenditures in an industry. The idea that the degree of activity in asset resale markets affects financial contractibility is formalized in Shleifer and Vishny (1992). To construct this measure, starting from 1981, we hand-collect data for used and new capital acquisitions at the four-digit SIC level from the Bureau of Census' *Annual Survey of the Manufacturers*. Our results (untabulated) are qualitatively similar when we proxy for asset tangibility using this alternative measure.

We also examine whether industry dynamics may influence our results by experimenting with industry–time fixed effects. This approach addresses, for example, potential biases associated with developments in industry competition that affect investment and might be correlated with the main elements of our story (*Tangibility* and *Q*). Our results (untabulated) show that the introduction of industry × time interaction effects does not alter our inferences about the credit multiplier effect.

4.2. Tests on debt capacity and debt taking

Our theory on the multiplier effect of asset tangibility on investment is predicated on the notion that tangibility enhances external financing capacity; in particular, that it helps support additional debt financing. While the results thus far are consistent with this hypothesis, we have not examined the empirical relation between debt financing and investment that underlies the credit multiplier. We do so in this section. Specifically, expanding our testing approach, we perform a number of experiments considering the role of incremental ("spare") debt capacity and debt taking decisions.

4.2.1. Debt capacity

Our tests suggest that asset tangibility helps constrained firms obtain more credit following positive innovations to investment opportunities. As a result, they invest more in response to those innovations. Until now, the tests concerning this idea were performed without explicitly accounting for firm financing. In other words, we did not consider whether the firm's *ex-ante* indebtness would influence the extent to which firms take advantage of the enhanced debt capacity provided by investment in tangible assets. For instance, if a firm is already highly indebted prior to the positive shock to investment, then it should be less able to invest as a function of asset tangibility; that is, the credit multiplier would be weaker or even fail. In contrast, the credit multiplier is likely to be more pronounced when innovations affect firms with more spare debt capacity.

It is difficult to gauge a firm's *ex-ante* debt capacity. However, our theory provides for a viable, albeit potentially incomplete, characterization of incremental debt capacity. Recall, we argue that the ability to obtain credit is a increasing function of a firm's asset tangibility. Accordingly, the correlation between the firm's leverage and the degree of its asset tangibility could provide information about the firm's spare debt capacity: if a firm carries less (more) leverage on its balance sheet than other firms with similar asset tangibility, then that firm is likely to have higher (lower) incremental debt capacity.[12]

This insight helps us construct an empirical proxy for spare debt capacity. That proxy is based on the component of a firm's long-term debt that is *not* explained by the firm's asset tangibility. This component can be directly gauged from the residuals of a regression of *Leverage* (or, item #9 ÷item #6) on *Tangibility*. While the magnitude of those regression residuals may be of little economic interest, they are useful in gauging spare debt capacity in that they can be employed to rank firms into categories. We proceed in this way, ranking firm-years into a "high" ("low") debt capacity category if the leverage regression residuals associated with those firm-years fall into the bottom (top) three deciles of the distribution of the residuals. To check that the results we obtain from this experiment are economically sensible, we also rank firms into low and high debt capacity according to their lagged, raw leverage ratios. Both of these rankings are performed on an annual basis.

Table 8 shows what happens when we condition our interactive models on firms' spare debt capacity. Panel A presents results for the debt capacity sorting scheme that is based on leverage residuals. Panel B is similarly structured, but high and low debt capacity categories are based on rankings of raw leverage ratios. Only financially constrained firms are used to perform our tests, since only those firms' investment is affected by the credit multiplier. The results presented in Panels A and B of Table 8 are remarkably strong and internally consistent. They show that, among constrained firms, the credit multiplier reported in previous tables (e.g., Table 5) is strongest across firms with high debt capacity, and non-existent across firms with low debt capacity. This is exactly what one should expect given the dynamics of the credit multiplier implied by our theory.

4.2.2. Debt taking

We argue that asset tangibility magnifies the impact of investment opportunities on observed investment spending through a financing channel. This happens because of a feedback effect between

[12] In the capital structure literature, Campello (2006) uses a related approach.

Table 8

Investment spending, Q, and asset tangibility: debt capacity and the credit multiplier effect. This table displays OLS-FE (firm- and year-fixed effects) estimation results of the credit multiplier investment model (Eq. (31) in the text), where constrained firms are split into "high" and "low" debt capacity groups. In Panel A, firms are assigned into high and low debt capacity categories according to annual rankings of the residuals from a regression of firm leverage on asset tangibility. Low (high) residuals are associated with high (low) incremental debt capacity. In Panel B, annual rankings based on raw leverage are used. Accordingly, firms ranked at the bottom (top) of the leverage distribution are considered to have high (low). *Investment* is the ratio of fixed capital expenditures (item #128) over lagged fixed capital stock (item #8). *Q* is computed as the market value of assets divided by the book value of assets, or (item #6 + (item #24 × item #25) – item #60 – item #74)/(item #6). *Tangibility* is an annual, firm-level proxy for expected value of assets in liquidation (the computation follows Berger et al. (1996)). *Leverage* is computed as item #9 divided by item #6. All firm data are collected from COMPUSTAT's annual industrial tapes over the 1971–2005 period. The sample firms are from manufacturing industries (SICs 2000–3999). The estimations correct the error structure for heteroskedasticity and clustering using the White-Huber estimator. Robust standard errors reported in parentheses.

Dependent variable	Independent variables			R^2	Obs.
Investment	*Q*	*Tangibility*	*Q × Tangibility*		
Panel A: Debt capacity rankings based on the residuals from a regression of leverage on asset tangibility					
Financial constraints criteria					
1. Low payout firms					
High debt capacity	−0.0280	0.4258***	0.2443***	0.10	6597
	(0.0418)	(0.0778)	(0.0719)		
Low debt capacity	0.0674	0.3860***	0.0341	0.03	8002
	(0.0543)	(0.0941)	(0.0914)		
2. Small firms					
High debt capacity	0.0103	0.5727***	0.1439***	0.08	5945
	(0.0584)	(0.0988)	(0.0377)		
Low debt capacity	0.0354	0.5676***	0.0739	0.04	3455
	(0.0635)	(0.1381)	(0.1167)		
3. Firms without bond ratings					
High debt capacity	0.0178	0.3544***	0.0903*	0.06	16,936
	(0.0311)	(0.0519)	(0.0517)		
Low debt capacity	0.0863	0.4581***	0.0320	0.04	9806
	(0.0610)	(0.1031)	(0.1040)		
4. Firms without CP ratings					
High debt capacity	0.0178	0.3544***	0.0903*	0.06	16,936
	(0.0311)	(0.0519)	(0.0517)		
Low debt capacity	0.0919*	0.3522***	0.0107	0.03	14,784
	(0.0492)	(0.0819)	(0.0848)		
Panel B: Debt capacity rankings based on the distribution of leverage					
Financial constraints criteria					
1. Low payout firms					
High debt capacity	0.4092***	−0.4615**	0.4497***	0.07	5380
	(0.2857)	(0.2215)	(0.2811)		
Low debt capacity	0.6424***	0.1367	0.2384	0.02	7569
	(0.1829)	(0.1768)	(0.2145)		
2. Small firms					
High debt capacity	0.5042	0.0051	0.7951**	0.04	4800
	(0.3178)	(0.3053)	(0.3762)		
Low debt capacity	0.7933**	0.3840	0.1874	0.03	3376
	(0.3151)	(0.3367)	(0.4030)		
3. Firms without bond ratings					
High debt capacity	0.6233***	−0.0507	0.7382***	0.04	11,202
	(0.1767)	(0.1751)	(0.2174)		
Low debt capacity	0.7606***	0.4667**	−0.0400	0.02	8211
	(0.2017)	(0.2285)	(0.2753)		

(*continued on next page*)

Table 8 (*continued*)

Dependent variable	Independent variables			R^2	Obs.
Investment	*Q*	*Tangibility*	*Q* × *Tangibility*		
4. Firms without CP ratings					
High Debt Capacity	0.6527***	−0.0681	0.7555***	0.06	16,936
	(0.1724)	(0.1619)	(0.2022)		
Low Debt Capacity	0.6620***	0.2577	0.0488	0.02	12,115
	(0.1564)	(0.1571)	(0.1901)		

* Statistical significance at the 10% (two-tail) test level.
** Statistical significance at the 5% (two-tail) test level.
*** Statistical significance at the 1% (two-tail) test level.

Table 9
Debt taking, *Q*, and asset tangibility: the credit multiplier effect on debt policy. This table displays OLS-FE (firm- and year-fixed effects) estimation results of the credit multiplier debt model (Eq. (32) in the text). The dependent variable is *DebtIssuance*, defined as the change in long- (Δitem #9) and short-term debt (Δitem #34) over lagged total assets. The estimations use pre-determined firm selection into "financially constrained" and "financially unconstrained" categories. Constraint category assignments use ex-ante criteria based on firm dividend payout, asset size, bond ratings, and commercial paper ratings (see text for details). *Investment* is the ratio of fixed capital expenditures (item #128) over lagged fixed capital stock (item #8). *Q* is computed as the market value of assets divided by the book value of assets, or (item #6 + (item #24 × item #25) − item #60 − item #74)/(item #6). *Tangibility* is an annual, firm-level proxy for expected value of assets in liquidation (the computation follows Berger et al. (1996)). All firm data are collected from COMPUSTAT's annual industrial tapes over the 1971–2005 period. The sample firms are from manufacturing industries (SICs 2000–3999). The estimations correct the error structure for heteroskedasticity and clustering using the White-Huber estimator. Robust standard errors reported in parentheses.

Dependent variable	Independent variables			R^2	Obs.
DebtIssuance	*Q*	*Tangibility*	*Q* × *Tangibility*		
Financial constraints criteria					
1. Payout policy					
Constrained firms	−0.0523**	0.1342***	0.0701**	0.01	22,714
	(0.0229)	(0.0349)	(0.0326)		
Unconstrained firms	−0.0017	0.0587**	−0.0022	0.00	18,108
	(0.0236)	(0.0286)	(0.0369)		
2. Firm size					
Constrained firms	−0.0595**	0.1217***	0.0778**	0.01	15,432
	(0.0285)	(0.0335)	(0.0394)		
Unconstrained firms	−0.0057	0.1227***	0.0041	0.00	18,130
	(0.0234)	(0.0397)	(0.0377)		
3. Bond ratings					
Constrained firms	−0.0399*	0.1060***	0.0501**	0.01	45,644
	(0.0224)	(0.0269)	(0.0224)		
Unconstrained firms	0.1049	−0.0219	0.2082	0.01	11,181
	(0.0925)	(0.1501)	(0.1664)		
4. Comm. paper ratings					
Constrained firms	−0.0434**	0.1049***	0.0598***	0.01	52,381
	(0.0219)	(0.0273)	(0.0222)		
Unconstrained firms	0.0878	0.2740*	−0.1646	0.01	4444
	(0.1070)	(0.1604)	(0.1829)		

* Statistical significance at the 10% (two-tail) test level.
** Statistical significance at the 5% (two-tail) test level.
*** Statistical significance at the 1% (two-tail) test level.

investment and financing in the presence of financing constraints — our theory predicts that the two processes should move in tandem. We empirically test this logic by turning to firms' debt taking behavior. We do so in a regression framework in which debt taking (*DebtIssuance*) is on the left-hand side, while on the right-hand side we include the set of drivers we used for tests on investment. This empirical specification is represented by Eq. (32) above.

Table 9 reveals several interesting aspects of our debt taking tests. First, as reported by prior studies, leverage is negatively associated with Q and positively associated with *Tangibility*. Second, the estimates for tangibility interacted with Q substantiate the dynamics of our credit multiplier: (1) constrained firms take on more debt in response to increases in investment opportunities when their assets are more tangible; (2) unconstrained firms' investment is unaffected by the credit multiplier effect. The results for the debt taking model provides further evidence that *Tangibility* and Q jointly influence investment spending via a financing channel in the presence of credit imperfections.

Before concluding, it is worth noting that the results in Table 9 suggest that firms with very high asset tangibility (above the 75th percentile of the distribution of *Tangibility*) observe no direct relation between Q and *DebtIssuance* — i.e., the Q-interaction term dominates the Q-intercept term. Notably, this is similar to the relation between Q and *DebtIssuance* across financially unconstrained firms. At lower levels of *Tangibility*, however, increases in Q are met with sharp declines in debt. These findings are at the very heart of the impact of financing constraints on corporate policies. Our estimates imply that contracting imperfections can lead to a negative association between investment opportunities and external financing, but that this adverse effect can be attenuated by variables that enhance the contracting environment, such as asset tangibility. This firm-level effect is similar to the arguments made by Bernanke et al. (1996, 2000) in their pioneering work on the credit multiplier in the aggregate economy. These authors argue that the impact of financing imperfections stemming from agency problems and asymmetric information issues are minimized when firms have enough collateral. In that case, firms borrow from the capital markets whenever they are hit by positive innovations in investment opportunities. As collateral values drop, however, financing frictions become more relevant. Firms with good prospects (higher Q) then shy away from borrowing funds in the credit markets.

5. Concluding remarks

We model the effect of asset tangibility and financing constraints when financing and investment are jointly determined. For financially constrained firms, acquiring assets that can be used as collateral alleviates *ex post* hold-up problems and hence enlarges *ex ante* debt capacity. This, in turn, speeds up investment timing. Our model predicts that financially constrained firms with more tangible assets invest more and borrow more in response to positive shocks due to an endogenous financing–investment feedback effect that propagates across time — the *firm-level credit multiplier*.

Our model's central insights guide us in conducting empirical tests to shed new light on the relation between investment spending and Q. More specifically, while both Q and tangibility are expected to explain the firm's investment, the credit multiplier predicts that the *interaction* of these two variables should have an even stronger impact on investment in the cross-section of financially constrained firms. Based on a large sample of manufacturers over the 1971–2005 period, a variety of tests strongly support our theory's predictions. Consistent with our identification strategy, we show also that the credit multiplier is absent from samples of financially unconstrained firms and financially constrained firms with low incremental debt capacity. Finally, estimation results on debt issuance as a function of Q, tangibility, and Q interacted with tangibility lend further support to our firm-level credit multiplier effect. In particular, when firms are financially constrained, they take on more debt in response to increases in investment opportunities when their assets are more tangible.

The set of results generated by this study suggests that further extension of this research agenda may prove fruitful. More generally, our findings indicate that contracting imperfections may have important, yet understudied implications for corporate financial decisions. In future research, it would be interesting to examine whether the time-varying quality of collateral or the exposure to business cycle dynamics can, for example, explain differences in the complexity and evolution of debt structures and financial leverage ratios over time, and across firms. Likewise, it would be interesting to examine whether collateral alleviates external contracting problems in ways that affect various financial policies of the firm (such as cash management, dividend distributions, and leases).

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