Corporate Investment and Financing under Asymmetric Information*

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Abstract

We develop a dynamic model of corporate investment and financing decisions in which corporate insiders have superior information about the firm’s growth prospects. We show that firms with positive private information can credibly signal their type to outside investors using the timing of corporate actions and their debt-equity mix. Using this result, we show that asymmetric information induces firms with good prospects to speed up investment, leading to a significant erosion of the option value of waiting to invest. Additionally, we demonstrate that informational asymmetries may not translate into a financing hierarchy or pecking order over securities. Finally, we generate a rich set of testable implications relating firms’ investment and financing strategies, abnormal announcement returns, and external financing costs to a number of managerial, firm, and industry characteristics.

Keywords: asymmetric information; financing decisions; endogenous financing constraints; corporate investment; real options.

JEL Classification Numbers: G13, G14, G31, G34.
Introduction

Ever since Myers and Majluf (1984) showed that adverse selection could induce firms to bypass profitable projects and lead to a pecking order among securities, distortions in investment and financing policies resulting from informational asymmetries have been the subject of considerable research in corporate finance. Although we have learned much from this work, virtually all of the existing models are static and focus either on investment or on financing decisions. This has made it difficult to develop tests of the connection between investment and finance and, to date, empiricists have struggled identifying the effects of asymmetric information on corporate policy choices. In this paper, we advance the literature by developing a dynamic model of investment and financing with endogenous financing constraints arising from adverse selection. We then use this dynamic model to shed light on existing empirical results, generate a rich set of testable predictions, and offer insights and implications as to why the pecking order is not strictly observed empirically.

A prerequisite for our study is a model that captures in a simple fashion the effects of asymmetric information on firms’ policy choices. In this paper, we base our analysis on a dynamic real options model in which firms’ investment and financing strategies are jointly and endogenously determined. While standard real options models assume that firms have enough resources to fund investment or that the capital market has unlimited access to information, we consider instead an environment in which firms need to raise outside funds from uninformed investors to finance capital expenditures. Our paper addresses a set of key questions in corporate finance. First, how does investment policy reflect the informational advantage of corporate insiders? Second, how does asymmetric information affect financing decisions, i.e. the debt-equity mix and the cost of external funds? Third, how do investment and financing decisions interact and what are the factors that drive these interactions?

We consider, as in McDonald and Siegel (1986), a firm that has a valuable real investment opportunity. In order to undertake the investment project, the firm needs to raise outside funds by issuing securities. The firm has flexibility in the timing of its investment and financing decisions and can choose to issue debt or equity. The investment project, once completed, produces a stochastic stream of cash flows that depend on firm type. There are two types of firms in the economy: good type (high cash flow) firms and bad type (low cash flow) firms. Firm types are private information, so that insiders know more about the value of the firm’s
investment opportunities than potential investors. When making investment and financing decisions, management acts in the best interests of the incumbent stockholders.

The model demonstrates that while under perfect information different types of firms choose different investment policies and issue fairly priced claims, this need not be the case when outside investors are imperfectly informed about the firms’ growth prospects. With asymmetric information, the low type has incentives to mimic the high type and sell overpriced securities. Hence, in a pooling equilibrium in which all firms raise funds and invest at the same time, asymmetric information reduces (increases) the value of high-type (low-type) firms and increases (reduces) their cost of investment. This forces good firms to delay investment and bad firms to speed up investment compared to the perfect information benchmark. Because asymmetric information raises the cost of external funds for good firms, these firms may try to separate by imposing mimicking costs on bad firms.

We show in the paper that good firms can separate from bad firms by changing their investment and financing policy. Notably, we are the first to show that by accelerating investment – i.e. by reducing the value of the project at the time of investment – firms with good prospects can eliminate the benefits of mimicking for other firms and signal their positive information to outside investors. Although these distortions in investment policy have a cost, they allow good firms to obtain better terms for the claims they issue. We show that when the cost of distorting investment is lower than the underpricing cost due to adverse selection, firms with positive private information will choose to invest early to signal their type. That is, a central message from our analysis is that informational asymmetries imply investment behavior that differs substantially from that of standard real options models with perfect information.

The possibility for firms to signal their type through the timing of investment also has important implications for capital structure decisions. Static signaling models usually predict that when outside funds are necessary, firms prefer debt to equity because of the lower information costs associated with debt issues. While this pecking order hypothesis should perform best among firms that face particularly severe adverse selection problems, Frank and Goyal (2003) find that small high-growth firms often issue equity in lieu of issuing debt (see also Helwege and Liang, 1996, and Leary and Roberts, 2009). Our model reveals that firms can signal their private information to investors using the timing of corporate actions and, thus, that they can find ways to issue equity that avoid adverse selection costs, as conjectured by Fama and French (2005). As a result, asymmetric information may not translate into a preference
ranking over securities. In particular, one implication of our analysis is that equity issues can be more attractive than debt issues even for firms with ample debt capacity, consistent with the evidence in Leary and Roberts (2009).

Our theory of corporate investment and financing differs from existing contributions in three important respects. First, unlike most dynamic models of investment and costly external finance, financing constraints are endogenous in our framework, arising from adverse selection. Second, unlike most asymmetric information models, we consider dynamics. Third, we endogenize both investment and financing decisions. These unique features allow us to generate a rich set of testable predictions about firms’ investment rates, abnormal announcement returns, the probability of project failure after investment, and external financing costs.

We highlight the main empirical implications. First, our model predicts that adverse selection should lead firms to accelerate investment. Additionally, we find that firms with a higher market-to-book ratio or growth-potential should invest more readily. By contrast, cash flow volatility and operating leverage should diminish investment propensities. Another specific prediction of our model is that the dispersion in industry investment rates should be lower in industries that are more heavily debt financed and higher in industries with higher cash flow volatility or operating leverage.

Second, our theory predicts that the information released at the time of investment should trigger a positive jump in the value of the good type, consistent with the finding of McConnell and Muscarella (1985) that unexpected increases in investment lead to increases in stock prices. Another prediction of the model is that abnormal returns should be higher with debt financing than with equity financing, consistent with Masulis (1983). We also show that positive abnormal announcement returns following increases in capital expenditures should be limited to firms with good investment opportunities, as documented by Chan, Gau, and Wang (1995). A novel testable implication of the model is that, independently of the financing strategy of the firm, abnormal announcement returns should (i) decrease with the growth rate and volatility of the firm’s cash flow shock and (ii) increase with the growth differential between types, i.e., with the degree of valuation uncertainty prior to investment.

Third, since adverse selection problems are more severe for young, high-growth firms, another specific prediction of the model is that these firms will invest sooner so that their investment projects will have a greater likelihood of turning out poorly. Importantly, our
model generates unique predictions about the probability of project failure after investment. Notably we find that this probability should be negatively related to the size of abnormal announcement returns at the time of investment or to the degree of valuation uncertainty prior to investment. Finally, our model with endogenous financing constraints allows us to quantify financing costs and relate these to various firm and industry characteristics. We show that the cost of debt and equity are not constant, as often assumed in the literature on exogenous financing constraints. We show they are not even monotonic functions of the model parameters. For example, while worsening adverse selection may reduce investment in a model with exogenous financing constraints, we find that in our model it may encourage investment and discourage the use of debt.

The present paper relates to several contributions in the literature. Myers and Majluf (1984) are the first to analyze the effects of asymmetric information on investment and financing decisions. A key assumption in their model is that “the project evaporates if the firm does not go ahead at time \( t = 0 \) (pp. 190).” This paper considers instead that the firm has flexibility in the timing of investment. Hennessy, Livdan, and Miranda (HLM, 2009) examine investment and financing decisions in a model with repeated signaling and short-lived private information. HLM find that while bad types do not use debt (and so not all firms adhere to the cash-debt-equity pecking order), good types in their model always use the least information sensitive financing vehicle – debt over equity. In HLM, firms signal through financing only. In our model, good firms can signal their type through the timing of investment. This can lead them to prefer equity over debt.

Grenadier and Wang (2005) develop a real options model to examine the effects moral hazard on investment timing. Our paper differs from theirs in two respects. First, we consider that firms have to raise funds to invest. Second, we abstract from owner-manager conflicts and focus instead on insider-outsider conflicts, as in Myers and Majluf (1984). These differences have important implications for equilibrium investment strategies. Notably, while Grenadier and Wang find that moral hazard leads to late investment, we show that adverse selection leads to early investment. Grenadier and Malenko (2010) present a variant of our setup with a continuum of types and show our main qualitative results are robust. In their analysis, Grenadier and Malenko constrain firms to finance the capital expenditure with equity. In addition, they focus exclusively on separating equilibria. Our analysis of investment and financing decisions and of pooling equilibria allows us to determine in which economic environments it will be
optimal for firms to distort investment (rather than pool or distort financing) and to generate a rich set of testable implications on firms’ policy choices. Another difference between the two models is that Grenadier and Malenko have an agency component (with a managerial contract that is specified exogenously), making it more difficult to interpret their results.

Finally, our paper also relates to the line of research that studies the magnitude of investment and financing distortions due to conflicts of interest between inside equityholders and outside investors (see Mello and Parsons, 1992; Morellec, 2001; Hennessy and Whited, 2007; Sundaresan and Wang, 2007; Hackbarth and Mauer, 2010; and Morellec and Schührhoff, 2010). None of these papers have examined the effects of adverse selection on the cost of external finance and firms’ investment and financing strategies.

The paper is organized as follows. Section one describes the model. Section two explores the effects of asymmetric information on firms’ equilibrium investment strategies. Section three introduces debt financing. Section four develops the model’s empirical predictions. Section five concludes. Technical developments are gathered in the Appendix.

1 Model and assumptions

This paper considers a firm that must issue securities to invest in a risky project. Management knows more about project quality than potential investors. The firm has discretion over the timing of investment as well as the timing and type of security issuance. Investors interpret the firm’s actions rationally and use Bayes’ rule to update their beliefs. An equilibrium model of the issue-invest decision is developed under these assumptions.

1.1 Setup

The model is an adaptation of Myers and Majluf (1984) and McDonald and Siegel (1986). Throughout the paper, financial markets are competitive. Agents are risk neutral and discount cash flows at a constant rate \( r \). We consider a set of infinitely-lived firms, each of which has monopoly rights to an investment project. The direct cost of investment is constant, denoted by \( I \), and investment is irreversible. The project, once completed, produces a continuous stream of cash flows. We assume that the level of cash flows depends on firm type, which is
indexed by \( k \). Specifically, at any time \( t \) after investment, a firm of type \( k \) generates a profit flow given by \( \Lambda_k X_t - f \) where \( \Lambda_k > 0 \) is known to corporate insiders only, \( f > 0 \) represents constant operating expenses, and \( X_t \) is an observable cash flow shock that evolves according to:

\[
dX_t = \mu X_t \, dt + \sigma X_t \, dZ_t, \quad X_0 > 0.
\]

In this equation, the growth rate \( \mu < r \) and volatility \( \sigma > 0 \) of the cash flow shock are constant and \((Z_t)_{t \geq 0}\) is a standard Brownian motion. We consider that there are two types of firms – high growth (good type \( g \)) and low growth (bad type \( b \)) firms – so that \( \Lambda_k \) has discrete sample space \( \{\Lambda_b, \Lambda_g\} \), with \( \Lambda_g > \Lambda_b > 0 \) and \( \Pr(\Lambda_k = \Lambda_g) = p \in (0,1) \). Before investment, firm types are private information, i.e., are known to corporate insiders only.

The initial capital structure of each firm consists of \( n_k^- = 1 \) share of common equity. To fund the project the firm sells risky debt or new equity. Following Myers and Majluf (1984), we assume that when making investment and financing decisions, management acts in the old stockholders’ interests by maximizing the intrinsic value of existing shares, which equals the selling price of the shares when investors have full information. We also assume that when the firm issues shares, old stockholders are passive so that the issue goes to a different group of investors. We denote by \( n_k^+ = 1 + \Delta n_k \) the number of shares outstanding after the round of financing and by \( c \) the selected debt coupon payment. When the capital outlay is financed with risky debt, the decision to default is endogenous and chosen by shareholders. In default, bankruptcy costs consume a fraction \( \alpha \in (0,1] \) of the firm’s revenue stream.

### 1.2 Investment timing under symmetric information

Before analyzing the effects of asymmetric information on equilibrium investment strategies, we start by reviewing the benchmark case in which all agents have full information about the firms’ investment projects. Since debt financing induces deadweight costs of bankruptcy and claims are fairly priced, it is optimal for firms to finance the capital expenditure by issuing \( \Delta n_k \) shares of common equity in this full information benchmark.

Denote by \( V_k^- \) the value of type \( k \)'s project before investment and by \( \Pi(x) \) the present value of a perpetual stream of cash flows \( X \) starting at \( X_0 = x \):

\[
\Pi(x) = \mathbb{E} \left[ \int_0^\infty e^{-rt} X_t \, dt \middle| X_0 = x \right] = \frac{x}{r - \mu}.
\]

\(^1\)This assumption is not crucial and can easily be relaxed (see Grenadier and Malenko, 2009).
Similarly, denote by \( F \) the present value of operating expenses, i.e. \( F = \int_0^\infty e^{-rt} f \, dt = \frac{f}{r} \). Because the firm does not generate any income before investment, old shareholders are only entitled to the capital gain \( \mathbb{E}[dV^-_k] \) over each time interval \( dt \). The required rate of return for investing in the firm’s equity is \( r \). Applying Itô’s lemma, it is then immediate to show that the value of equity before investment satisfies:

\[
rv^-_k = \frac{1}{2} \sigma^2 X^2 \frac{\partial^2 V^-_k}{\partial X^2} + \mu X \frac{\partial V^-_k}{\partial X}, \quad \text{for } k = g, b. 
\]

This equation is solved subject to the following boundary conditions. First, the value of equity at the time of investment is equal to the payoff from investment (value-matching):

\[
V^-_k(X)|_{X=X_k} = \Lambda_k \Pi(X_k) - F - I, \quad \text{where } X_k \text{ is the threshold selected by type } k = g, b. \]

In addition, to ensure that investment occurs along the optimal path, the value of equity satisfies the smooth pasting condition: \( \frac{\partial V^-_k}{\partial X}|_{X=X_k} = \Lambda_k \frac{\partial \Pi(X)}{\partial X}|_{X=X_k} \) at the endogenous investment threshold (see Dixit and Pindyck, 1994). Finally, as the value of the cash flow shock tends to zero, the option to invest becomes worthless so that \( \lim_{X \to 0} V^-_k(X) = 0 \).

Solving this optimization problem yields the following expression for equity value in the perfect information benchmark (all proofs are relegated to the Appendix):

\[
V^-_k(X) = [\Lambda_k \Pi(X_k) - F - I] \left( \frac{X}{X_k} \right)^\xi, 
\]

where the value-maximizing investment threshold \( X_k \) is given by:

\[
X_k = \frac{\xi}{\xi - 1} \frac{r - \mu}{\Lambda_k} (F + I), \quad \text{for } k = g, b. 
\]

and \( \xi = \frac{(\sigma^2/2 - \mu)/\sigma^2 + \sqrt{[(\sigma^2/2 - \mu)/\sigma^2]^2 + 2r/\sigma^2}}{1} > 1 \). Eq. (4) shows that equity value can be written as the product of the surplus created by investment (term in brackets) and the present value of \( \$1 \) contingent on investment, given by \( (X/X_k)^\xi \). The investment threshold in Eq. (5) reflects the option value of waiting through the factor \( \xi/(\xi - 1) \). If this option had no value, shareholders would follow the simple NPV rule, according to which one should invest as soon as \( X \geq X^0_k = (r - \mu)(F + I)/\Lambda_k \). Importantly, since \( X_g < X_b \), high-type firms invest before low-type firms in the full information benchmark. Finally, under perfect information

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\(^2\)For now we ignore the option to abandon assets to keep the analysis tractable. We will examine the effects of exit/default on equilibrium investment and financing policies when we introduce debt. Any intermittent cash shortfalls can be covered through external equity without frictional costs as any asymmetric information is resolved by the time the firm’s productive assets operate.
outside (equity) financing is costless and the firm achieves the same value as if it was financing the capital expenditure itself. The number of shares issued by type $k$ is defined by the budget constraint: $\Delta n_k[\Lambda_k \Pi(X_k) - F] = I(1 + \Delta n_k)$.

### 1.3 Investment timing and signaling

While under perfect information different types of firms choose different investment thresholds and issue fairly priced claims, this need not be the case when outside investors are imperfectly informed about firms’ growth prospects. Indeed, since $\Lambda_g > \Lambda_b$, we have $V^-_g > V^-_b$ and there is an incentive for the bad type to sell overpriced securities by means of mimicking the good type’s behavior. In a pooling equilibrium, in which all firms invest at the same time and have the same market value, asymmetric information imposes costs on high-type firms – they need to dilute their equity stake more than they would otherwise. As a result, good type firms may try to separate by imposing mimicking costs on bad type firms. In the following, we show under which conditions this is feasible.

Suppose the firm invests at date $t$ for a value $X_t$ of the cash flow shock. Let the firm type perceived by investors be $\Lambda$, $\Lambda_b \leq \Lambda \leq \Lambda_g$. Since investors need to break even in expectation, investors’ beliefs about firm type determine the number of shares, $\Delta n(X_t; \Lambda)$, that need to be issued at the time of financing. The required number of shares solves the budget constraint: $\Delta n(X_t; \Lambda)[\Pi(X_t) - F]/n^+(X_t; \Lambda) = I$, the solution to which is given by:

$$\Delta n(X_t; \Lambda) = \frac{I}{\Pi(X_t) - F - I}.$$  

Eq. (6) reveals that the benefit of being perceived as a higher type $\Lambda$ translates into a larger equity stake for incumbents. More generally, it shows that the higher the type $\Lambda$ and the larger the investment trigger $X$, the lower the ownership dilution. Proposition 1 shows under which conditions the first effect dominates the second so that the single-crossing (or Spence-Mirlees) condition holds (see Appendix B for a proof):

**Proposition 1** High-type firms find it less costly to distort investment than low-type firms so long as $f > 0$, such that the single-crossing property holds globally:

$$\frac{\partial}{\partial \Lambda_k} \left( \frac{\partial}{\partial X} V_k(X; \Lambda) \right) > 0 \text{ for all } (\Lambda, X).$$
When deciding whether to mimic or separate, each firm type balances investment distortions with ownership dilution. As a result, the possibility for the good type to separate from the bad type relates to each type’s willingness to exchange equity stakes for changes in the investment threshold. The single-crossing condition in Proposition 1 asserts that firm type affects the marginal rate of substitution between investment distortions and ownership dilution in a systematic way. In particular, the elasticity between the competitively required ownership dilution $\Delta n(\bar{X}; \Lambda)$ and investment threshold $\bar{X}$ depends negatively on the type $k$ so long as $f \geq 0$. This implies that the high type may find it worthwhile to speed up investment and still realize a positive NPV on the project, while the bad type may face a negative NPV project at the same investment threshold. As a result, financial markets can reasonably view the timing of investment as a valid signal for project or firm quality.

For a general exercise value, $v(\Lambda, X)$ say, the single-crossing condition generalizes to the requirement that the elasticity with respect to the investment threshold, $v_2(\Lambda_k, \bar{X})/v_1(\Lambda_k, \bar{X})$, is decreasing in firm type $\Lambda_k$ or, equivalently, $v(\Lambda_k, \bar{X}) \leq v_1(\Lambda_k, \bar{X})v_2(\Lambda_k, \bar{X})/v_{12}(\Lambda_k, \bar{X})$, where the subscript $i$ denotes the partial derivative with respect to the $i$th argument. That is, when altering the timing of investment, the high type’s value needs to drop by less than the low type’s for it to act as valid signal, which in the case occurs if and only if $f > 0$. In the remainder of the paper, we consider that operating expenses $f$ are positive so that the timing of corporate actions represents a valid signal.

2 Signaling through investment timing

2.1 Investment timing in the separating equilibrium

Assume for now that the capital outlay is financed by issuing equity. Our objective in this section is to show that there exists a timing of investment (for the good type) that makes it possible to sustain a separating equilibrium in which the two types of firms choose different investment thresholds and issue fairly priced claims. The mechanism underlying the equilibrium is a simple one. When deciding whether to mimic or not, the low-type firm balances the overpricing of the shares (positive effect) with the reduction in intrinsic value due to the change in investment policy (negative effect). By speeding up investment, the high-type firm reduces the value of the project at the time of investment and, hence, reduces the benefits
of mimicking for the bad type. The question we want to address is whether there exists an investment threshold such that the good type finds it profitable to invest and the bad type does not find it profitable to mimic.

To determine whether there exists a separating equilibrium, we first need to check the incentive compatibility constraint (ICC) of the bad type. Suppose that the good type invests at date $t$ for a value $X_t$ of the cash flow shock. If the bad type mimics the investment behavior of the good type, the value of old shareholders’ claim in the bad firm after investment is given by:

$$\Lambda_b \Pi (X_t) - F \Lambda_g \Pi (X_t) - F \left[ \Lambda_g \Pi (X_t) - F - I \right],$$

since by mimicking the bad type only needs to issue a number of shares equal to $\triangle n(X_t; \Lambda_g)$ (given by Eq. (6)) to finance the capital expenditure. This equation shows that mimicking the good type reduces both the cost (equity dilution) and benefits (NPV) of investment. Instead of mimicking the good type, the bad type can follow its first-best strategy under perfect information, i.e., raise equity and invest when the cash flow shock reaches $X_b$. The bad type firm prefers mimicking the good type at $X_b$ if:

$$\Lambda_b \Pi (X) - F \Lambda_g \Pi (X) - I \geq \left[ \Lambda_b \Pi (X) - F - I \right] \left( \frac{X}{X_b} \right)^{\xi} = V_b^- (X).$$

Real option value $> 0$

Value when mimicking

At the 0-NPV threshold for the good type, $X^0_g = (F + I)/\Pi(\Lambda_g)$, the left-hand side of Eq. (9) is equal to zero whereas the right-hand side is positive (being an option value). In this case, it is better for the bad firm to wait and not mimic the good firm. At the value-maximizing investment threshold of the bad type, $X_b$, the left-hand side of Eq. (9) is larger than the right-hand side (since $I > 0$). In this case, it is better for the bad firm to mimic the good firm. These observations, combined with the strict monotonicity of $V_b^-(X)$, imply there exists a unique value $X^*$ of the cash flow shock, with $X^0_g < X^* < X_b$, such that good firms can separate from bad firms by raising funds and investing before the cash flow shock exceeds this value. The critical threshold $X^*$ is given by the solution to Eq. (9).

\[\text{We can restrict attention to values of the cash flow shock } X \leq X_b \text{ since all allocations with } X > X_b \text{ are incentive incompatible and pareto-dominated by corresponding allocations with } X \leq X_b. \text{ Consider the case that condition (9) holds for all } X \geq X^{**} > X_b \text{ such that the good type can separate by investing past } X^{**}. \text{ In this strategy profile, the bad type moves before the good type. After the bad type has moved, the uncertainty is revealed and beliefs should assign probability one to the good type for any } X > X_b. \text{ The good type then has no incentive to wait any longer, and the proposed strategy cannot be an equilibrium.}\]
To determine whether investing at or below $X^*$ is an equilibrium strategy, we need to verify incentive compatibility of the good type. The following incentive compatibility constraint is a necessary condition for the good type to separate from the bad type at $X \leq X_b$:

$$\frac{\Lambda_g \Pi(X) - F - I}{1 + \Delta n(X_b; \Lambda_b)} \geq \frac{\Lambda_g \Pi(X_b) - F}{\Lambda_b} \left( \frac{X}{X_b} \right) \xi.$$  \hfill (10)

Value in separating equilibrium Value when mimicking $> 0$

The threshold $X_{\text{min}}$ for which ICC (10) is binding represents the lowest value of the cash flow shock such that the good type prefers separation over mimicking. Since the value of the good type when mimicking is strictly positive, the separating investment threshold cannot be too close to the 0-NPV threshold. A separating equilibrium exists only if $X_{\text{min}} \leq X^*$. By the optimality of $X_g$ in the absence of information asymmetry, we also have $X_{\text{min}} \leq X_g$. Not all of the incentive compatible allocations $X \in [X_{\text{min}}, X^*]$ necessarily constitute a Perfect Bayesian equilibrium (PBE). A sufficient condition for a feasible threshold $X$ to be a PBE is that the good type has no incentive to defect to any other allocation $X$ given a set of out-of-equilibrium beliefs $\Lambda(X)$. It is straightforward to show that this is the case for all $X \in [X(\Lambda), X^*]$ where $X_{\text{min}} \leq X(\Lambda) \leq X^*$.

Using the incentive compatibility constraints of the good and bad types, it is immediate to establish the following result (proofs are relegated to Appendix C):

**Proposition 2** (i) There exists a separating equilibrium in which firms issue fairly priced claims and invest so long as $f > 0$. (ii) In the least-cost separating equilibrium good firms invest at the lower of the thresholds $X^*$ ($\geq X_{\text{min}}$) and $X_g$, while bad firms invest at their first-best threshold $X_b$. The market value of each firm before investment is independent of project quality and satisfies for $X < X^* \wedge X_g$:

$$V_{\text{fcs}}(X) = \begin{cases} \frac{\Lambda_g \Pi(X^*) - F}{\Lambda_g \Pi(X^*) - F} V_b^-(X), & \text{if } X^* < X_g, \\ \frac{p \Lambda_b^* + (1-p) \Lambda_b^+}{\Lambda_b^*} V_b^-(X), & \text{otherwise}, \end{cases}$$

where $\Lambda_{\text{pool}} = p \Lambda_g + (1-p) \Lambda_b$ and the market value under perfect information is defined in Eq. (4). The intrinsic value of the bad and good firms before investment are given by $V_b^-(X)$ and

$$V_{\text{fcs},g}(X) = \begin{cases} \frac{\Lambda_g \Pi(X^*) - F}{\Lambda_g \Pi(X^*) - F} V_b^-(X), & \text{if } X^* < X_g, \\ \left( \frac{\Lambda_g}{\Lambda_b} \right)^\xi V_b^-(X), & \text{otherwise}. \end{cases}$$  \hfill (12)
(iii) Good firms invest more aggressively than first-best \((X^* < X_g, \text{ i.e. overinvest})\) whenever

\[
\frac{\xi}{\xi - 1} \left[ \Lambda_b - \Lambda_g \left(\frac{\Lambda_b}{\Lambda_g}\right)^\xi \right] > \frac{F}{F + I} \left[ 1 - \left(\frac{\Lambda_b}{\Lambda_g}\right)^\xi \right].
\] (13)

Proposition 2 shows that there exists an investment threshold \(X^*\) solving Eq. (9) such that good types can separate from bad types by issuing equity and investing at or below that threshold. The good type will want to follow this strategy only if the cost of separating (i.e., the cost of investing early) is not too high compared to the underpricing of the shares. Since the value of the good type decreases with the selected investment threshold (for any threshold below \(X_g\)), this implies that there exists a lower bound \(X_{\text{min}} \leq X^*\) on the separating investment threshold. Finally, since investing early is costly for good firms, in the least-cost separating equilibrium the good firm will want to raise equity and invest the first time the cash flow shock reaches the lower of \(X^*\) and \(X_g\). The equilibrium characterized in Proposition 2 (ii) can be sustained under pessimistic beliefs (i.e., \(\Lambda(X) = \Lambda_b \forall X > X^* \land X_g\)). The good type then has no incentive to defect from \(X^* \land X_g\) to any other allocation. By applying the Intuitive Criterion of Cho and Kreps (1987), the least-cost separating contract is uniquely selected in equilibrium (as in, e.g., Hennessy, Livdan, and Miranda, 2009).

Importantly, while Grenadier and Wang (2005) show that moral hazard leads to late investment, our analysis demonstrates that adverse selection leads to early investment. This difference in equilibrium investment strategies is not surprising as, in the presence of owner-manager conflicts, the good type wants to hide its positive information about project values – and pool with the bad type – to extract more rents from the principal. As a result, the objective of the principal is to offer a contract to the agent that will induce truthful revelation. This can be achieved by making it more costly for the good type to pool with the bad type, i.e. by delaying investment for the bad type. By contrast, in the presence of adverse selection, the good type wants to reveal its positive private information and the bad type wants to mimic the good type. It is therefore optimal for the good type to speed up investment, to make it more costly for the bad type to mimic.

### 2.2 Discussion

**Investment timing:** One of the major contributions of the real options literature is to show that with uncertainty and irreversibility, there exists a value of waiting to invest so that firms
should only invest when the asset value exceeds the investment cost by a potentially large option premium. This effect is well summarized in the survey by Dixit and Pindyck (1994). These authors write:

“We find that [...] the option value [of waiting] is quantitatively very important. Waiting remains optimal even though the expected rate of return on immediate investment is substantially above the interest rate or the normal rate of return on capital. Return multiples as much as two or three times the normal rate are typically needed before the firm will exercise its option and make the investment.”

Although this investment policy is consistent with what firms would do in the perfect information benchmark, it is not consistent with what they will do when taking into account informational asymmetries. As shown in Proposition 2, asymmetric information leads the good type to invest early in the project, as manifested by its decision to select an investment threshold \( X^* \) that is lower than the threshold \( X_g \) that maximizes project value. The intuition underlying this result is that when choosing whether to mimic the good type or not, the bad type balances the value of waiting to invest with the overpricing associated with a mimicking strategy. By investing early, the good type reduces the intrinsic value of the bad type at the selected investment threshold and, hence, the benefits of mimicking for the bad type. At the separating threshold, the cost of distorting investment becomes too high and the bad type no longer wants to mimic, allowing the good type to issue fairly priced claims.

![Insert Figure 1 Here](image1)

Fig. 1, Panel A, plots the value-maximizing investment threshold (solid blue line), the separating investment threshold (bold line), and the 0-NPV threshold (dashed green line) as a function of the growth potential of the high type \( \Lambda_g \), the volatility of the cash flow shock \( \sigma \), and operating leverage \( F \). We use the following parameter values: the risk-free rate \( r = 5\% \), the volatility and growth rate of cash flow shock: \( \sigma = 25\% \) and \( \mu = 1\% \), operating leverage \( F = 10/r \), the growth potential of the good and bad firms: \( \Lambda_g = 1.25 \) and \( \Lambda_b = 1.4 \). Fig. 1

\(^{4}\) The risk free rate is taken from the yield curve on Treasury bonds. The growth rate of cash flows has been selected to generate a payout ratio consistent with observed payout ratios. The firm’s payout ratio reflects the sum of the payments to both bondholders and shareholders. Following Huang and Huang (2002), we take the weighted averages between the average dividend yields (4% according to Ibbotson and Associates) and the average historical coupon rate (close to 9%), with weights given by the median leverage ratio of S&P 500 firms (approximately 20%). Similarly, cash flow volatility is chosen to match the (leverage-adjusted) asset return volatility of an average S&P 500 firm’s equity return volatility, as in Strebulaev (2007).
reveals the following. An increase in volatility decreases the bad firms’ incentives to mimic and allows good firms to invest later, since the value of the option to invest increases with the volatility of the cash flow shock.\(^5\) An increase in the size of the growth option for good firms \(\Lambda_g\) leads first to an increase in the benefits of mimicking and hence in a decrease of the separating threshold. After some critical value, however, mimicking becomes punitively expensive so that the separating threshold approaches first best. Finally, as operating leverage increases, the cost of mimicking for the bad type increases and distortions in investment decline.

**Cost of adverse selection:** By distorting investment, asymmetric information reduces the value of the good firm. This reduction in value is equal to the difference between the value of the firm under the value-maximizing investment policy and the value of the firm under the selected investment policy. Fig. 1, Panel B, plots this drop in value, defined by \(\frac{(V_g^{-}(X) - V_{lcs,g}^{-}(X))}{V_g^{-}(X)}\), as a function of the growth potential of the high type \(\Lambda_g\), the volatility of the cash flow shock \(\sigma\) and operating leverage \(F\). The figure reveals that the reduction in project value can reach 30%. The comparative statics mirror those in Panels A since greater investment distortions imply a larger reduction in firm value.

**Change in the stock price at the time of investment:** In the separating equilibrium, outside investors have incomplete information about the quality of the firms’ growth prospects before investment. However, at the time of investment, firm types become public information and this uncertainty is resolved. Because outside investors cannot predict when investment will take place, the information released at the time of the good type’s investment triggers a positive jump in the good type’s stock price and a negative price reaction in the bad type’s stock price. This is consistent with the finding of McConnell and Muscarella (1985) that unexpected increases in investment lead to increases in stock prices (and vice versa for unexpected decreases).

Denote by \(AR_k(X) = \frac{(V_k^+(X) - V_{lcs}^{-}(X))}{V_{lcs}^{-}(X)}\) the jump in the value of type \(k\) when the value of the cash flow shock is \(X\) where \(V_{lcs}^{-}(X)\) is defined in Proposition 2. At the time

\(^5\)Note that the threshold for investment in the perfect information benchmark increases more than the hurdle rate with adverse selection since the vega of an option increases with its moneyness (and the good type’s real option, determining \(X_g\), is more in the money than the bad type’s real option, determining \(X^*\)).
of investment (consider the case $X^* \leq X_g$), these abnormal returns are given by
\[
AR_g(X^*) = \frac{\Lambda_g \Pi(X^*) - F}{\Lambda_{pool} \Pi(X^*) - F} - 1 > 0, \quad \text{and} \quad AR_b(X^*) = \frac{\Lambda_b \Pi(X^*) - F}{\Lambda_{pool} \Pi(X^*) - F} - 1 < 0. \tag{14}
\]

Eq. (14) shows that the jump in the value of the good type at the time of investment is positive as investment at $X^*$ signals good news about project quality. By contrast, the jump in the value of the firm that does not invest (bad type) is negative. Fig. 1, Panel C, plots the abnormal announcement returns of the good type (solid blue line) and bad type (dashed red line) as a function of $\Lambda_g$, $\sigma$, and $F$. We set $p = 50\%$ in the base case. Because the timing of investment depends on the growth potential of each type, on the volatility of the cash flow shock and on the firm’s operating leverage, abnormal returns to shareholders depend on these factors as well. In particular, the model predicts that abnormal returns should decrease with the project’s cash flow volatility $\sigma$ and increase with the growth potential of the good type and operating leverage $F$ (since mimicking is more costly).

2.3 Pooling in equity: The underpricing-overinvestment trade-off

While the available evidence on abnormal announcement returns suggests that firms are often able to signal their private information to outside investors, the study of pooling equilibria provides additional insights on the determinants of firms’ policy choices.\textsuperscript{6} In a pooling equilibrium, financial markets are not able to distinguish among firms of different types. All firms invest at the same time and issue common equity to finance the capital outlay. The pooled value of the firms at the time of investment is given by
\[
V_{pool}^+(X) = \sum_{k=b,g} \Pr(\Lambda = \Lambda_k) \Lambda_k \Pi(X) - F = \Lambda_{pool} \Pi(X) - F. \tag{15}
\]

The constraint $V_{pool}^+(X) \Delta n(X; \Lambda_{pool})/[1 + \Delta n(X; \Lambda_{pool})] = I$ determines the number of shares that have to be issued at the time of investment given the value of the cash flow shock $X_{pool}$ at that time. Solving this budget constraint yields
\[
\Delta n(X_{pool}; \Lambda_{pool}) = \frac{I}{\Lambda_{pool} \Pi(X_{pool}) - F - I}. \tag{16}
\]

\textsuperscript{6}A conceptual drawback of the Intuitive Criterion applied in Proposition 2 is that equilibrium selection is insensitive to the prior distribution of types. Costly separation is unlikely, however, from an ex ante perspective when the fraction of high-type firms $p$ is close to one. In this situation a pooling contract can be beneficial for the good type, since its optimal pooling contract approaches the first-best allocation as $p$ tends to 1.
This equation shows that asymmetric information leads to a dilution of the good type’s equity stake. Ex post outside investors make money on the good type and lose money on the bad type: There is cross-subsidization.

To determine whether a pooling equilibrium exists, we first need to verify that pooling with the good type is an optimal strategy for the bad type. The incentive compatibility constraint of the bad type writes

\[
\frac{\Lambda_b \Pi(\bar{X}_{pool}) - F}{1 + \triangle n(\bar{X}_{pool}; \Lambda_{pool})} \geq \left[\Lambda_b \Pi(\bar{X}_b) - F - I\right] \left(\frac{\bar{X}_{pool}}{\bar{X}_b}\right)^\xi.
\]

Value in pooling equilibrium Real option value

Since \(\Lambda_{pool} < \Lambda_g\), the threshold at which condition (17) is binding lies between \(\bar{X}^*\) and the first-best threshold \(\bar{X}_b\). For smaller values of the cash flow shock, condition (17) is violated and investment at such a threshold does not constitute a pooling equilibrium.

As is standard in signaling games, we face multiplicity of equilibria. Maskin and Tirole (1992), however, show that in the mechanism design game in which the firm’s insiders (the ‘informed principal’) ex ante offer contracts to investors in the capital market (the ‘uninformed agents’), only those pooling equilibria survive that (weakly) pareto-dominate the least-cost separating equilibrium characterized in Proposition 2. In any pooling equilibrium all firms invest at the same time and issue common equity. The incentive compatibility constraint (17) for the bad type puts a Perfect Bayesian best-response restriction on the set of pareto-dominant pooling equilibria. The remaining restriction is that the value of the good type in the pooling equilibrium is larger than its value in the least-cost separating equilibrium:

\[
\frac{\Lambda_g \Pi(\bar{X}_{pool}) - F}{1 + \triangle n(\bar{X}_{pool}; \Lambda_{pool})} \left(\frac{X}{\bar{X}_{pool}}\right)^\xi \geq 1_{\bar{X}_g \leq \bar{X}^*} V_g^- (X) + 1_{\bar{X}_g > \bar{X}^*} \left(\frac{\Lambda_g \Pi(\bar{X}^*) - F}{\Lambda_b \Pi(\bar{X}_b) - F}\right) V_b^- (X).
\]

Value in pooling equilibrium Value in separating equilibrium

Pooling equilibria exist if and only if there is a threshold \(\bar{X}_{pool}\) for which conditions (17) and (18) hold. We can check these conditions as follows. Whenever \(\bar{X}_g \leq \bar{X}^*\), condition (18) is violated since the good type cannot do better than the first-best value \(V_g^-\). Consider next the reverse situation. The best pooling equilibrium for type \(k\) is the one that selects the
investment threshold \( \bar{X}_{pool,k} \) that maximizes the present value \( V_{pool,k}^- (X) \) of the cash flows accruing to incumbent shareholders. We show in Appendix D that

\[
\bar{X}_{pool,k} = \frac{\chi_k}{\chi_k - 1} \frac{r - \mu}{\Lambda_{pool}} (F + I), \quad k = g, b
\]

where \( \chi_k > 1 \) depends on firm type. There will therefore not be a single pareto-optimal pooling equilibrium. Notice, however, that condition (17) holds whenever condition (18) is satisfied. A pooling equilibrium therefore exists if and only if \( \bar{X}^* < \bar{X}_g \) and condition (18) holds at \( \bar{X}_{pool,g} \). We then have the following existence result (see the appendix):

**Proposition 3** There exists a pareto-dominant pooling equilibrium in which all firms issue equity and invest the first time the cash flow shock reaches a threshold \( \bar{X}_{pool} \) satisfying (17) and (18) with \( \bar{X}^* \leq \bar{X}_{pool} \leq \bar{X}_b \) if and only if condition (13) holds (so that \( \bar{X}^* < \bar{X}_g \)) and the fraction of good projects in the economy, \( p \), exceeds the threshold \( \bar{p} \) defined in Appendix D.

The next proposition characterizes the pareto-dominant pooling equilibria:

**Proposition 4** Good firms invest more conservatively than first best (underinvest) and bad firms invest more aggressively than first best (overinvest) in the pooling equilibrium, that is \( \bar{X}_g \leq \bar{X}_{pool} \leq \bar{X}_b \). The market value in the pooling equilibrium is independent of project type, and market and intrinsic values are equal to

\[
V_{pool}^- (X) = [\Lambda_{pool} \Pi (\bar{X}_{pool}) - F - I] \left( \frac{X}{\bar{X}_{pool}} \right)^{\xi} \quad \text{and} \quad V_{pool,k}^- (X) = \frac{[\Lambda_k \Pi (\bar{X}_{pool}) - F] V_{pool}^- (X)}{\Lambda_{pool} \Pi (\bar{X}_{pool}) - F}.
\]

Several important results follow from Proposition 4. First, asymmetric information lowers the investment threshold selected by the bad type compared to the perfect information benchmark. As a result, asymmetric information causes bad firms to speed up investment or overinvest relative to first best, consistent with the evidence in Kedia and Philippon (2009). Second, asymmetric information reduces the value of good firms and increases the value of bad firms. Thus, although the good type can raise the funds required to finance its project, it is hurt by the presence of the bad one.

Insert Figure 2 Here
Fig. 2 plots the least-cost equilibrium (Panel A), the equilibrium investment threshold (Panel B), the external financing costs (Panel C), and the underpricing of the shares issued in the pareto-dominant pooling equilibrium (Panel D) for the high-type firm as a function of the growth potential of the high type $\Lambda_g$, the volatility of the cash flow shock $\sigma$, operating leverage $F$, and investors’ belief about the fraction of high-type firms $p$ in the economy (depicted on the vertical axis in Panel A). Input parameter values are set as in Fig. 1. In Panels B–D, we assume that the fraction of high-type firms in the economy is $p = 50\%$. The figure shows that for low values of operating leverage $F$, cash flow volatility $\sigma$, or growth differential $\Lambda_g/\Lambda_b$, it is too costly for the good type to separate so that pooling equilibria pareto-dominate the least-cost separating equilibrium. When this is the case, the good type underinvests relative to first best and there is no abnormal announcement return.

One essential difference between our analysis and the analysis in Myers and Majluf (MM, 1984) is that MM assume that “the investment opportunity evaporates if the firm does not go ahead at time $t = 0$. (pp. 190)” In the current paper we make the opposite assumption and consider that each firm can delay investment as much as it desires. In Appendix E, we consider the effects of timing constraints on equilibrium investment strategies and show that that the model of Myers and Majluf is nested in ours. Notably, we demonstrate that in the limit as the firm cannot postpone investment, the option value of waiting to invest vanishes and firms face a now-or-never investment decision. When this is the case, both types of firms want to invest immediately as long as the pooled net present value of the project is positive and only pooling equilibria in equity survive.

3 Signaling through investment and financing choice

We have thus far not explored the possibility that firms might issue debt to finance the capital expenditure. In this section, we relax this assumption and examine the effects of debt financing on firms’ equilibrium investment strategies. While good types can separate from bad types by issuing equity and investing earlier than first best, we show they can also separate by issuing debt (as in Leland and Pyle, 1977). We demonstrate in this section that the equilibria can be Pareto-ranked and that the least-cost financing choice depends on investors’ prior beliefs about project quality and on the project’s characteristics.\footnote{For lack of space we restrict attention to situations in which firms issue only one type of financing instrument. A mix of debt and equity could be incorporated in the model and would be a nice extension. External}
3.1 Debt issuance and firm valuation with perfect information

Suppose that the investment outlay $I$ is funded with risky perpetual debt with coupon flow $c$. Denote the default threshold of type $k$ by $X_k(c)$. In the perfect information benchmark, the total value of the firm $V^+_k$ and the value of debt $D_k$ after investment are given by the following expressions for $k = g, b$ (see Appendix F):

$$V^+_k(X, c) = \Lambda_k \Pi(X) - F - \alpha \Lambda_k \Pi \left( \frac{X}{X_k(c)} \right)^\nu, \quad (20)$$

$$D_k(X, c) = \frac{c}{r} - \left[ \frac{c}{r} - (1 - \alpha) \Lambda_k \Pi (X_k(c)) + F \right] \left( \frac{X}{X_k(c)} \right)^\nu, \quad (21)$$

where $\nu = (\sigma^2/2 - \mu)/\sigma^2 - \sqrt{[(\sigma^2/2 - \mu)/\sigma^2]^2 + 2r/\sigma^2} < 0$. Eq. (20) shows that for any value of the cash flow shock, debt financing reduces firm value by inducing bankruptcy costs (third term on the right-hand side). In Eq. (21), the first term on the right-hand side is the value of risk-free debt. The second term captures the impact of default risk on the value of corporate debt. The intrinsic value of equity is in turn given by $V^+_k(X, c) - D_k(X, c)$, $k = g, b$, and the endogenous default threshold satisfies (see Appendix F):

$$X_k(c) = \frac{\nu}{\nu - 1} \left( \frac{r - \mu}{\Lambda_k} \right) (F + \frac{c}{r}), \quad k = g, b. \quad (22)$$

Since $\Lambda_g > \Lambda_b$, Eq. (22) implies that for a given coupon payment $c$ the default threshold of the good firm is lower than the default threshold of the bad firm.\(^8\)

In order to simplify the exposition, define the coefficients $\eta$ and $\eta_k$ as follows:

$$\eta = \frac{\alpha \nu}{\nu - 1 - (1 - \alpha) \nu}, \quad \text{and} \quad \eta_k = 1 - \frac{\Lambda_k^{\nu}(1 - \eta)}{p\Lambda^\nu_g + (1 - p)\Lambda^\nu_b}. \quad (23)$$

Under symmetric information, the budget constraint $D_k(X, c_k(X)) = I$ uniquely determines the coupon $c_k(X)$ selected by type $k$ at the time of investment ($c_k(X)$ is given by expression (F.10) in Appendix F). The credit spread on the debt contract is then given by $\rho_k(X) = c_k(X)/I - 1$ at the date of issuance, and firm value at the investment date satisfies financing is associated with substantial fixed costs including advisory, legal, regulatory fees and underwriter expenses. This often forces firms to choose between instruments. Common equity and straight debt are the most popular public financing vehicles for U.S. corporations.

\(^8\)This result is robust to alternative bankruptcy policies. For instance, if the firm is constrained from raising additional funds, it defaults when $X_k(c) = \frac{c}{\Lambda_k}$, $k = g, b$, and we again have $X_g(c) < X_b(c)$. 19
\( V_k^+(X, c_k(X)) = \Lambda_k \Pi(X) - F - \eta \rho_k(X) I \). The third term in this expression captures the discount due to deadweight costs of default.

In the perfect information benchmark, a firm of type \( k \) optimally invests when the cash flow shock reaches the investment threshold \( \bar{X}_{k,D} \) defined by

\[
\bar{X}_{k,D} = \bar{X}_k \left[ 1 + \frac{\eta \rho_k I}{I + F} \left( 1 - \frac{\nu [F + (1 + \rho_k) I]}{\xi [F + (1 + \nu \rho_k) I]} \right) \right] > \bar{X}_k. \tag{24}
\]

Since the term in brackets is larger than unity, Eq. (24) shows that debt financing delays investment. This is due to the increase in the cost of capital from deadweight losses in default. Firm value before investment is then given by

\[
V_{k,D}^{-}(X) = \frac{F + (1 + \nu \frac{1-\alpha}{1-\alpha \nu} \rho_k) I}{F + (1 + \nu \rho_k) I} \left( \frac{\bar{X}_k}{\bar{X}_{k,D}} \right)^\xi V_k^{-}(X), \quad k = g, b. \tag{25}
\]

This expression reveals that debt financing reduces firm value through two channels in the perfect information benchmark. First, for a given investment policy, debt financing induces bankruptcy costs (first factor on the right-hand side of this equation). Second, debt financing distorts investment policy (second factor).

### 3.2 Separation through debt issuance

In the perfect information benchmark, equity issuance maximizes firm value because debt financing induces deadweight costs of default and investment distortions (i.e. \( \bar{X}_{g,D} > \bar{X}_g \)). However, in the presence of informational asymmetries, issuing equity may not be in the best interests of incumbent shareholders as it may lead to underpricing in a pooling equilibrium or to large investment distortions in a separating equilibrium.

To determine whether there exists a separating equilibrium in which the good type issues debt, we first need to check the incentive compatibility constraint of the bad type. The budget constraint \( D_g(X, c_g) = I \) implies that the bad type is indifferent between mimicking the good type by issuing debt at the threshold \( \bar{X}_{D}^* \) and waiting to follow its first-best strategy if the following incentive compatibility constraint is satisfied:

\[
V_{b}^+(\bar{X}_{D}^*, c_g(\bar{X}_{D}^*)) - I + \underbrace{\left[ \left( \frac{\Lambda_b}{\Lambda_g} \right)^\nu - 1 \right]}_{\text{Cross-subsidization}} \rho_g(\bar{X}_{D}) I = \left[ \Pi(\bar{X}_{D}^*) - F - I \right] \left( \frac{\bar{X}_{D}}{\bar{X}_b} \right)^\xi. \tag{26}
\]
This incentive compatibility constraint is similar to that derived under equity financing and reflects the fact that cross-subsidization reduces the cost of debt financing for the bad type 
\[ D_b(X, c_g) = I \left[ 1 - \left( \Lambda_b^* \Lambda_g r^* - 1 \right) \rho_g(X) \right] < I \]. The positive effect of selling overpriced debt is counter-balanced by the investment distortions \( \bar{X}^*_D \neq \bar{X}_b \) and the negative effect of bankruptcy costs on the value of the bad type after investment (captured in the term \( V_b^+ \)). When the value of the cash flow shock is below \( \bar{X}_D \), the bad type prefers to invest at its first-best trigger \( \bar{X}_b \). Otherwise, the bad type prefers to mimic the good type.

To determine whether issuing debt and investing below the threshold \( \bar{X}_D \) is an equilibrium strategy for the good firm, we also need to check its incentive compatibility constraint:
\[
V_g^+(X, c_g(X)) - I \geq \frac{\Lambda_g \Pi(\bar{X}_b) - F}{1 + \Delta n(\bar{X}_b; \Lambda_b)} \left( \frac{X}{\bar{X}_b} \right)^\xi, \tag{27}
\]
where \( V_g^+(X, c_g(X)) \) is given in Eq. (20). The threshold \( \bar{X}_{g,D} \) for which the incentive compatibility constraint (27) is binding represents the lowest value of the cash flow shock such that the good type prefers separation with debt over pooling with the bad type. A separating equilibrium in debt exists only if \( \bar{X}_{g,D} \leq \bar{X}_D \). By the optimality of \( \bar{X}_{g,D} \) in the absence of information asymmetry, we also have \( \bar{X}_{g,D} \leq \bar{X}_{g,D} \). Finally, for a feasible threshold \( \bar{X} \in [\bar{X}_{min,D}, \bar{X}_D] \) to be a PBE the good type must not want to defect to any other debt- or equity-financed investment policy. Combining these results, we obtain the following Proposition:

**Proposition 5** (i) There exists a separating equilibrium in which growth firms separate by issuing debt and investing the first time the cash flow shock reaches \( X \) satisfying \( \bar{X}_{min,D} \leq X \leq \bar{X}_D \) so long as \( \Lambda_b/\Lambda_g, \sigma, \) and \( f \) are low enough and \( \mu \) is large enough. (ii) In the unique least-cost separating equilibrium with debt, good firms invest at the lower of the thresholds \( \bar{X}_D \) and \( \bar{X}_{g,D} \), while bad firms invest at their first-best investment threshold \( \bar{X}_b \).

The selected coupon payment \( c_g \) and the credit spread \( \rho_g \) are determined by condition (F.10) in Appendix F. Before investment firm value is independent of project quality and satisfies:
\[
V_{los,D}(X) = pV_{g,D}(X) + (1 - p)V_b^-(X). \tag{28}
\]

(iii) Separation in debt is least-cost if and only if
\[
\frac{F + (1 + \nu_0 \rho_g)I}{F + \nu \rho_g I} \left( \frac{\bar{X}_b}{\bar{X}_{g,D}} \right)^\xi \geq \max \left[ 1_{X_g \leq \bar{X}} \left( \frac{\Lambda_g}{\Lambda_b} \right)^\xi + 1_{X_g > \bar{X}} \frac{\Lambda_g \Pi(\bar{X}^*) - F}{\Lambda_b \Pi(\bar{X}^*) - F} \frac{V_{pool,g}(X)}{V_b^-(X)} \left( \frac{\Lambda_g}{\Lambda_b} \right)^\xi \right], \tag{29}
\]

21
where $V^-_{pool,g}(X)$ is defined in Proposition 4.

Proposition 5 shows that there exists an investment threshold $X^*_D$ solving Eq. (26) such that good types can separate from bad types by issuing debt and investing at or below that threshold. The good type will follow this strategy only if the cost of separating (i.e., the cost of issuing debt and distorting investment) is not too high compared to the underpricing of the shares. Since the value of the good type increases with the selected investment threshold (for any threshold below $X_{g,D}$), this implies that there exists a lower bound $X_{\min,D} \leq X^*_D$ on the separating investment threshold. Finally, since distorting investment is costly, in the least-cost separating equilibrium the good firm issues debt and invests the first time the cash flow shock reaches the lower of $X^*_D$ and $X_{g,D}$.\(^9\)

### 3.3 Least-cost equilibrium

Given that several investment and financing strategies are available, one question that naturally arises is what is the value-maximizing strategy for the good type? The traditional answer to this question is that firms should first issue the securities with the lowest information costs, i.e. that informational asymmetries make conventional equity issues unattractive. Proposition 5 shows that in our model the financing choice of the good type is determined by a trade-off between investment distortions, the more severe underpricing of equity, and the deadweight costs of default associated with risky debt claims.

![Insert Figure 3 Here](image)

Fig. 3, Panel A, maps out the least-cost equilibrium (as characterized in Proposition 5) as a function of the various parameters of the model. The figure shows that when $\Lambda_g/\Lambda_b$ is

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\(^9\)With two-dimensional signals – timing and financing choice – the space of deviations to consider is now larger. This has the effect that some of the equity equilibria derived in Section 2 become incentive incompatible, since it may be profitable for the good type to deviate from accelerated investment at $X^*$ to delayed investment and debt issuance, even under pessimistic out-of-equilibrium beliefs. The results in this and the next section, nonetheless, are unaffected. The parameter combinations where such deviations are relevant coincide with those satisfying condition (29), where equity is dominated by debt issuance and the debt-financed investment strategy characterized in Proposition 5 (ii) is the least-cost separating equilibrium. Similarly, debt-financed investment policies where the good type wants to deviate to equity-financed investment are dominated by equity pooling or separating equilibria.
high, the good type finds it optimal to separate from the bad type by issuing equity, as it is too costly for the bad type to distort its investment strategy in that case. By contrast, when \( \Lambda_g / \Lambda_b \) is small both types pool in equity. These results are due to the fact that the value of the option to invest is increasing and concave in the selected investment threshold so that the cost to the bad type of deviating from its first best threshold is increasing and convex. Separation with debt issuance is the optimal strategy for intermediate values of \( \Lambda_g / \Lambda_b \).

When deciding which type of security to issue, the good type balances the investment distortions associated with equity issues and the expected bankruptcy costs of debt. Fig. 3 reveals that high bankruptcy costs, high cash flow volatility, large operating leverage, or a large growth differential between types makes it more likely for the good type to issue equity. This suggests that, consistent with the evidence reported by Frank and Goyal (2003), small high-growth firms may not find it optimal to behave according to the static pecking order theory. Hence our model can explain observed departures from this theory such as equity issuance by firms with ample debt capacity.

As in the case of equity financing, we can examine the implications of debt financing for investment distortions (Panels B) and announcement returns (Panel C). Fig. 3 plots these quantities as a function of the relative size of the growth option of bad firms, \( \Lambda_b / \Lambda_g \), the volatility of the cash flow shock \( \sigma \) and operating leverage \( F \). Input parameter values are set as in Fig. 1. The figure shows that when separation in debt is least-cost, good firms select an investment threshold that is higher than the first best threshold (i.e. \( \bar{X}_{g,D} \geq \bar{X}_g \); see Eq. (24)). Since the timing of investment depends on the size and volatility of the cash flows generated by the firms’ investment project and on operating leverage, the figure reveals that abnormal returns depend on these factors as well (Panel C). In particular, the model predicts that abnormal returns should decline with volatility \( \sigma \) and the fraction \( p \) of good firms, and rise with the growth differential \( \Lambda_g / \Lambda_b \) and operating leverage \( F \).

4 Implications and empirical predictions of the model

Over the past two decades, the literature examining the relation between external finance constraints and corporate investment has developed substantially. Most of the theoretical contributions in this area model financing frictions exogenously and loosely relate these frictions to moral hazard or adverse selection problems. Our model adds to this literature by
allowing us to examine explicitly the effects of endogenous financing constraints arising from adverse selection on firms’ equilibrium investment and financing strategies, abnormal returns following the announcement of corporate policy choices, and external financing costs.

### 4.1 Endogenous financing constraints and corporate investment

Table 1 summarizes the investment and financing behavior of the good and bad firms in each of the three types of equilibrium: separating in equity, pooling in equity, and separating in debt. The table shows that pooling equilibria in equity and separating equilibria in debt lead to late investment for the good type compared to the perfect information benchmark, while separating equilibria in equity lead to early investment.

| Insert Table 1 Here |

To quantify the effects of adverse selection on the timing of investment, we can examine the relation between asymmetric information and a firm’s investment hazard, defined as the probability of undertaking the project as a function of time (as in Whited, 2006). In our model, the probability of investment over the next $t$ years can be computed as (see e.g. Harrison, 1985, pp15):

$$ F(t) = \Pr \left[ \sup_{s \in [0,0+t]} X_s \geq K \right] = N \left[ \frac{\ln(X_0/K) + mt}{\sigma \sqrt{t}} \right] + \left( \frac{K}{X_0} \right)^{\frac{2m}{\sigma^2}} N \left[ \frac{\ln(X_0/K) - mt}{\sigma \sqrt{t}} \right], \tag{30} $$

where $m \equiv \mu - \sigma^2/2$, $N$ is the standard normal cumulative density function, $K = \bar{X}_g$ or $K = \bar{X}_b$ under perfect information, $K = X^* \wedge \bar{X}_g$ in separating equilibria, and $K = \bar{X}_{pool}$ in pooling equilibria.

Fig. 4 plots the probability of investment as a function of time under adverse selection for high-type (solid line) and low-type (dotted line) firms in comparison with the probability of investment under the first-best investment policy (dashed line). We compute this probability when firms separate and when firms pool (dash dotted line). The top chart in each panel plots the cumulative probability of investment $F(t)$ given in expression (30), while the bottom chart plots the hazard rate $F'(t)/(1 - F(t))$. Across panels we vary the initial value of the cash flow shock. Input parameter values are set as in the base case environment, with the fraction
of good projects given by $p = .5$ in the separating equilibrium and by $p = .7$ in the pooling equilibrium.

Fig. 4 shows that in the separating equilibrium, adverse selection speeds up investment compared to the perfect information benchmark and that the effect is quantitatively important. In the separating equilibrium, constrained firms invest more (i.e., the hazard rate is higher) and have a higher marginal productivity of capital (i.e., only the good firms with a high $\Lambda$ accelerate investment). By contrast, Fig. 4 shows that in the pooling equilibrium firms cannot signal their quality to outside investors and end up investing later than first best. The quantitative effect is limited, however, since pooling is optimal for the good type only if the cost of the investment distortion is not too high. As discussed in Section 2, a similar investment pattern would emerge in a model in which frictions are generated by moral hazard. In such models, the optimal contract between the principal and the agent implies an increase the investment threshold of the bad type to induce truthful revelation. By contrast, in the separating equilibrium, firms with positive private information speed up investment to make it more costly for firms with negative private information to mimic.

The behavior of constrained firms in the separating equilibrium is consistent with the empirical findings in Hall (1987), Evans (1987), and Dune and Hughes (1994) that small (and presumably more financially constrained) firms invest more and grow faster than large firms. It also fits the standard folklore that smaller firms are more aggressive at entering new markets or launching new products than bigger, safer, and financially unconstrained firms. Importantly, a recent study examining private firms’ decisions to go public by Bustamante (2009) provides direct evidence supporting our theory. Her empirical analysis reveals that firm age is a significant characteristic in firms’ decisions to exercise their option to do an IPO. She also finds that the probability of receiving a high rating by Standard & Poor’s in the years following an IPO on the NYSE is negatively and significantly related to the age of the firm at the time of the IPO, consistent with the prediction of the model that good firms invest early. Finally, the prediction that firms underinvest when separating in debt is consistent with the negative relation between “market leverage” (measured as the value of debt divided by the value of the firm) and growth options documented in the literature examining the relation between firms’ leverage choices and the composition of their investment opportunity sets (see Smith and Watts, 1992, Rajan and Zingales, 1995, or Barclay, Morellec, and Smith, 2006).
To make the analysis complete, Table 2 examines the determinants of investment hazards. To do so, we first perform the simulation experiment described in Appendix G, generating a set of 60,000 artificial firms from our model. We then regress investment hazards on a set of characteristics. Specifically, we first compute the theoretical investment hazard rates at different points in time in the simulated data. We then estimate how this hazard function depends on observed firm characteristics. Explanatory variables that accelerate investment are expected to raise hazards for small $T$ and lower hazards for large $T$, and vice versa. The construction of the explanatory variables is discussed in the appendix.

Consistent with the above discussion, firms with a higher market-to-book ratio, a higher growth-potential, or a larger probability of being successful invest more readily. By contrast, cash flow volatility and bankruptcy costs diminish investment propensities.\(^\text{10}\)

**Investment rates, financing, and industry characteristics:** While our model has implications for the investment decisions of individual firms, it also has direct implications for the dispersion in industry investment rates. In particular, our theory predicts that this dispersion should be greatest when firms separate in equity. Indeed, when firms separate in equity (respectively in debt), the investment threshold of the good type is below (above) the investment threshold in the perfect information benchmark and hence further away from (closer to) that of the bad type. As shown in Section 3, firms are more likely to separate in equity when the degree of valuation uncertainty, the volatility of cash flows, or operating leverage are higher. By contrast, our theory predicts that the dispersion in industry investment rates should be

\(^\text{10}\)The negative effect of the rate of cash flow growth on the investment hazard comes from the fact that we set the initial value of the cash flow shock at the zero NPV threshold of the full information benchmark, defined by $X_0 = (r - \mu)(F + I)/\Lambda_g$. Since this zero NPV threshold is more sensitive to changes in $\mu$ than the equilibrium investment threshold, an increase in $\mu$ implies that the starting value of the cash flow shock is further away from the investment threshold (thereby reducing the probability of investment). Alternatively, we could have fixed the initial value of the cash flow shock independently of its growth rate. In this case, the rate of cash flow growth would have had a positive effect on the investment hazard. However, with $X_0$ fixed, one has to either set $X_0$ very low in order not to have cases where immediate investment is optimal (which implies that the probability of investment is very low) or one gets many immediate investment cases. Importantly, the choice of the initial value for the cash flow shock has no bearing on the sign of the relation between the investment hazard and the other explanatory variables in Table 2.

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lower in industries that are more heavily debt financed. These predictions on the dispersion in industry investment rates are unique to our theory.

Another robust prediction of our model is that, since operating leverage facilitates separation for high type firms through accelerated investment, investment rates should appear inefficiently high in high operating leverage industries (separating equilibrium) and inefficiently low in low-leverage industries (pooling equilibrium), compared to first best. This prediction is opposite to neoclassical models of investment with fixed costs of adjustment and differential operating leverage (see Whited, 2006). In a neoclassical model higher operating leverage makes firms less profitable; so they optimally replace capital less often, which lowers investment hazards. This difference has not been tested, and is a way to distinguish the two classes of theories.\(^{11}\)

### 4.2 Adverse selection and ex-post losses

In the perfect information benchmark, firms invest with a large option premium over the cost of investment, resulting in a significant cushion against future market downturns. As a result, the probability of real asset values falling below investment cost is very low. This prediction is clearly at odds with the recent empirical evidence on the behavior of real estate markets or on the high exit rate of firms in many industries. In the analysis below, we examine the effects of adverse selection on the potential for future investment losses and derive a number of new empirical implications.

To illustrate the effects of adverse selection on the likelihood of ex-post losses, we can compute the probability that, given a value \(X_\tau\) of the cash flow shock at the time of investment, the asset value (net of operating costs) falls below the investment cost over the next \(T\) years. This probability is given by (see Harrison, 1985, pp. 15):

\[
\Pr \left[ \inf_{t \in [\tau, \tau + T]} \Lambda_k \Pi(X_t) - F \leq I \right] = \left( \frac{a_k}{X_\tau} \right)^{\frac{2m}{\sigma^2}} N \left[ \frac{\ln \left( \frac{a_k}{X_\tau} \right) + mT}{\sigma \sqrt{T}} \right] + N \left[ \frac{\ln \left( \frac{a_k}{X_\tau} \right) - mT}{\sigma \sqrt{T}} \right],
\]

where \(a_k \equiv (r - \mu)(F + I)/\Lambda_k\), \(m \equiv \mu - \sigma^2/2\), \(N\) is the normal cumulative distribution function, \(X_\tau = X_g\) under perfect information, and \(X_\tau = X^* \land X_g\) under asymmetric information. In the base case environment, asymmetric information increases the probability of ex-post losses.

\(^{11}\)We thank the referee for pointing this out to us.
over a five year horizon from 13% to 23%, showing that the effects of adverse selection can be significant. Since adverse selection problems are more severe for young, high-growth firms, an immediate consequence of the model is that these firms will invest sooner so that their investment projects will have a greater likelihood of turning out poorly.

To get more insights on the determinants of the probability of ex-post losses, Fig. 5 plots this probability in the separating equilibrium (which is the focus of most empirical studies) over a five-year horizon (changing the horizon would change the magnitude of the probability but not its functional form). We focus on three determinants of the probability of ex-post losses, namely operating leverage, the growth potential of the good type, and the volatility of the cash flow shock. In each plot, we report the probability of ex-post losses under the first-best investment policy (dashed line) and in the separating equilibrium (solid line). In addition, we plot in Panel B the abnormal announcement returns that had been computed in Fig. 1 against the loss probability for the same set of parameter values.

One interesting testable implication that comes out of our model is that the probability of ex-post losses should be negatively related to the size of abnormal announcement returns at the time of investment. Indeed, we can observe in Fig. 5 that abnormal announcement returns increase with the growth potential of the good type and operating leverage and decrease with volatility. By contrast, the probability of ex-post losses decreases with the growth potential of the good type and operating leverage and increases with volatility. Similarly, because the size of announcement returns depends on the degree of valuation uncertainty (as measured by the difference in project quality) prior to the announcement of the investment decision, another testable implication of our model is that the likelihood of ex-post losses should be negatively related to the degree of valuation uncertainty.

Our model also allows to generate empirical implications on the expected time to ex-post losses. Denote by $T$ the first time that real asset values fall below investment cost. We have for $\sigma^2 > 2\mu$:

$$
E[T] = \lim_{r \to 0} \frac{\partial E[e^{-rT}]}{\partial r} = \frac{1}{\sigma^2/2 - \mu} \ln \left( \frac{\Lambda_k \Pi(X_\tau)}{F + I} \right).
$$

In this equation, $X_\tau = X_g$ under perfect information, and $X_\tau = X^* \wedge X_g$ under asymmetric information. In the separating equilibrium, an increase in the quality of the good type makes
it more costly for the bad type to mimic and hence allows the good type to invest closer
to first best, thereby reducing the probability of ex-post losses. As a result, another testable
implication of our model is that the lag between the time of investment and the first occurrence
of sustained operating losses should increase with abnormal announcement returns at the
time of investment and with the degree of valuation uncertainty prior to investment. These
empirical predictions are again unique to our theory.

4.3 The debt-equity choice

So far the analysis has focused on the predictions of the model for the timing of investment
and the likelihood of operating losses following investment, that is the asset side of the balance
sheet. In this section, we perform a simulation experiment using the procedure described in
Appendix G (see also Berk, Green, and Naik, 1999, or Strebulaev, 2007) to validate that
the predictions of the model are consistent with the data on financing. For this purpose, we
simulate a total of \( N = 60,000 \) artificial firms and construct explanatory variables for the
debt-equity choice similar to the ones used in recent empirical studies (see e.g. Leary and
Roberts, 2009). The construction of the explanatory variables is discussed in Appendix G.

In the model, the debt-equity choice is a nonlinear function of input parameter values. This
relation can be linearized, yielding a binary choice equation like the one typically estimated
in the empirical literature. Therefore, the specification we estimate takes the form of a simple
discrete choice model for the financing vehicle. Let \( e_i = 1 \) when equity issuance is the least-cost
financing vehicle according to the model, and \( e_i = 0 \) otherwise. Denote by \( y^*_i \) the projection
of the net benefit of equity over debt issuance on a vector \( x_i \) of observable characteristics and
proxies for the model parameters, defined by \( y^*_i = \theta' x_i + \epsilon_i \). Then \( e_i = 1 \) is equivalent to
\( y^*_i \geq 0 \) and we have

\[
Pr(e_i = 1) = Pr(\epsilon_i \geq -\theta' x_i).
\]

When \( \epsilon_i \) follows a normal (logit) distribution, estimating the parameters \( \theta \) amounts to a probit
(logit) regression.

Table 3, Panel A, summarizes the estimation results for different specifications. Consistent
with the empirical literature on the financing choice between equity and debt, and in contrast
to the pecking order hypothesis, the model predicts that equity issuance is more prominent
in small firms with sizeable investment opportunities, that is for small high M/B firms, and
when cash flow volatility, leverage, and default costs are high (see e.g. Leary and Roberts, 2009). The remaining columns show that these results are robust to the specification and the assumption on the error term distribution. The second column restricts the explanatory variables to observables and uses the alternative M/B definition, and the last column performs a logit estimation. The results are similar to those in the first column.

Using the estimated regression parameters $\theta$, we can compute predicted probabilities for the financing decision. These can then be used to evaluate the ability of a linear discrete choice model to replicate the choice probabilities from the structural model. We follow Leary and Roberts (2009) and first determine the empirical likelihood of an equity issuance in the simulated data, $\pi = \frac{1}{N} \sum_i e_i$. The firm’s predicted financing choice is equity issuance if $\Pr(e_i = 1) \geq \pi$. As in Leary and Roberts (2007), the exact choice of threshold (\(\pi\) rather than a 0.50 cutoff) has little impact on our conclusions since we are interested in the model’s ability to characterize financing decisions as a whole.

Table 3, Panel B, summarizes the prediction accuracy of the model. In 82% to 95% of cases the empirical model predicts the correct financing choice. These numbers compare favorably with the classification accuracy of probit/logit regressions applied on Compustat data. This confirms that the explanatory variables used in empirical studies can capture the impact of asymmetric information on financing choices.

4.4 Additional implications and empirical predictions

Our model predicts that real and financial decisions should be jointly determined and that financing decisions, abnormal announcement returns, and the costs of outside funds should depend on a number of firm- and industry-specific factors. Table 4 summarizes these predictions for the different types of equilibria.

While many of our predictions on financing decisions are shared with others theories and, hence, have already been tested (see the discussion below), most of the other predictions in Table 4 are unique to our theory and provide grounds for further empirical work.
Cost of outside funds: Our model with endogenous financing constraints allows us to quantify financing costs and to relate these to observable characteristics. Fig. 3, Panel D, plots the cost of financing as a function of the various parameters of the model. The figure shows that the cost of outside funds are not constant, as often assumed in the literature on exogenous financing constraints (see e.g. Gomes, 2001). The cost of outside funds are not even a monotonic function of the model parameters. For example, while worsening adverse selection may reduce investment in a model with exogenous financing constraints, it may actually encourage investment and discourage the use of debt. Similarly, a change in the volatility of the cash flow shock may lead to a change in the firm’s financing strategy and, hence, may not imply a monotonic response of the costs of outside funds. We explore these differences further in Table 5.

Table 5 reports the determinants of external financing costs in the least cost equilibrium. The estimates are obtained by regressing financing costs on a set of characteristics using a sample of 60,000 artificial firms generated from the model. Consistent with Fig. 3, high market-to-book firms face higher funding costs, while cash flow growth and volatility and measures of project quality ($\Lambda_g$ and $p$) diminish overall costs.

Abnormal announcement returns: Consider next abnormal equity returns in the time window surrounding the public announcement of investment and financing decisions. The model predicts that independently of the type of separating equilibrium that prevails, abnormal announcement returns should decrease with the growth rate and volatility of the firm’s cash flow shock. The model also predicts that abnormal announcement returns should increase with the growth differential between types, i.e., with the degree of valuation uncertainty prior to investment. Finally, the model predicts that abnormal returns should be higher with debt financing than with equity financing (see Fig. 3). While most of these predictions on abnormal announcement returns are novel, this last prediction of the model is consistent with the positive return documented in debt for equity exchanges (see e.g. Masulis, 1983), even though the effect predicted by the model is small (consistent with the study of Eckbo, 1986). In addition, our model predicts that positive abnormal announcement returns following increases in capital expenditures should be limited to firms with good investment opportunities, as documented by Chan, Gau, and Wang (1995), and Chung, Wright, and Charoenwong (1998).
Characteristics of equity issuers: Our finding that firms will choose to finance some of their growth options by issuing equity is consistent with a number of recent empirical studies on firms’ investment and financing decisions (see e.g. Fama and French, 2005, or Frank and Goyal, 2003). These studies show that equity issues are common and that equity issuers are not typically under duress. In addition, and consistent with the predictions of our theory, Gatchev, Spindt and Tarhan (2009) find that firms issue equity to fund investments in intangible assets such as research and development and in funding internally developed investment opportunities (for which asymmetric information is more important) rather than external acquisitions. More generally, our model shows that even in the presence of asymmetric information, financing with equity is not a last resort. We show that firms do not follow the pecking order in financing decisions; they simply avoid issuing equity in ways that involve asymmetric information problems. This does not mean that asymmetric information is irrelevant. In fact the firms that decide to issue equity signal their quality by distorting investment. However, we find that, in such situations, the implications of asymmetric information for capital structure can become quite limited.

Pecking order theory vs. trade-off theory: Finally, an other relevant feature of our model is that some of its predictions on financing decisions could also arise from a standard trade-off model or from a model based on agency conflicts within the firm. In fact, the mechanism implementing the least-cost equilibrium in our model trades off the underpricing cost due to adverse selection with investment distortions and deadweight costs of bankruptcy. Based on this trade-off, our model predicts that the use of debt should decline with the quality of the good type’s investment opportunities, the volatility of the cash flow shock, bankruptcy costs, and operating leverage. The first prediction could also be generated by a model based on shareholder-debtholder conflicts (see e.g. Myers, 1977) or based on manager-shareholder conflicts (see e.g. Morellec, 2004). The last three predictions could be generated by a trade-off model in which optimal capital structure balances taxes with deadweight costs of bankruptcy (see e.g. Leland, 1994). One essential difference between our model and these competing theories is that investment and financing decisions provide information to outside investors and trigger abnormal announcement returns, consistent with the empirical evidence. Another important difference is that first-best trade-off models predict that firms should always issue some debt whereas our model can generate zero-leverage firms.
5 Conclusion

This paper develops a real options model to examine the effects of asymmetric information on investment and financing decisions when external funds are needed to finance investment. In the model, the firm’s financing and investment strategies are jointly determined and result from value-maximizing decisions. We show that by timing their decisions corporate insiders can communicate their private information about the firm’s prospects to outside investors. In particular, we show that by accelerating investment, firms with positive private information can make it more costly for firms with negative information to mimic and, hence, get better terms on the securities they issue. We then show that this result has a wide range of empirical implications for firms’ investment and financing policies, abnormal returns following the announcement of corporate policy choices, external financing costs, and the role of firm and industry characteristics in shaping corporate policies. Some of these predictions shed light on existing findings. Others are novel and provide grounds for further empirical work on corporate policy choices.
Appendix

A Investment timing with symmetric information

The required rate of return for investing in the firm’s equity is $r$. In turn, old shareholders only receive capital gains of $E[dV^-]_t$ over each time interval $dt$, because the firm does not produce any cash flows before investment. Thus, in the region for the cash flow shock where there is no investment ($X < X_k$), the value of the firm’s growth option satisfies:

$$rV_k^- = \frac{1}{2} \sigma^2 X^2 \frac{\partial^2 V_k^-}{\partial X^2} + \mu X \frac{\partial V_k^-}{\partial X}, \text{ for } k = g, b. \quad (A.1)$$

The solution of (A.1) is

$$V_k^- (X) = AX^\xi + BX^\nu, \quad (A.2)$$

where $\xi$ and $\nu$ are the positive and negative roots of the equation

$$\frac{1}{2} \sigma^2 y(y - 1) + \mu y - r = 0.$$  

Eq. (A.2) is solved subject to the following boundary conditions. First, the value of equity at the time of investment is equal to the payoff from investment (value-matching). In addition, to ensure that investment occurs along the optimal path, the value of equity satisfies the smooth pasting condition at the endogenous investment threshold (see Dixit and Pindyck, 1994). Finally, as the value of the cash flow shock tends to zero, the option to invest becomes worthless. In summary,

$$V_k^- (X) \bigg|_{X = X_k} = \Lambda_k \Pi(X_k) - F - I, \quad (A.3)$$

$$\frac{\partial V_k^-}{\partial X} \bigg|_{X = X_k} = \Lambda_k \frac{\partial \Pi(X)}{\partial X} \bigg|_{X = X_k}, \quad (A.4)$$

$$\lim_{X \to 0} V_k^- (X) = 0. \quad (A.5)$$

Condition (A.5) implies $B = 0$. Condition (A.3) implies $A = [\Lambda_k \Pi(X_k) - F - I](X_k)^{-\xi}$. Simple manipulations of (A.3) and (A.4) yield the expression for $X_k$.

B Single-crossing property

The valuation of type $k$ when signaling by investing at $\overline{X}$ and when the perceived type is $\Lambda$ equals

$$V_k(X; \overline{X}, \Lambda) = \frac{\Lambda_k \Pi(X)}{1 + \triangle n(X; \Lambda)} (\overline{X})^\xi = \frac{\Lambda_k \Pi(X)}{\Lambda \Pi(X) - F} [\Lambda \Pi(X) - F - I] \left( \frac{X}{\overline{X}} \right)^\xi. \quad (B.1)$$

This implies that we have

$$\frac{\partial}{\partial X} V_k(X; \overline{X}, \Lambda) = \left[ \frac{\Lambda_k \Pi(X)}{\Lambda_k \Pi(X) - F} - \frac{\Lambda \Pi(X)}{\Lambda \Pi(X) - F} \right] \frac{\Pi(X)}{\Lambda \Pi(X) - F - I} V_k(X; \overline{X}, \Lambda),$$

$$\frac{\partial}{\partial \overline{X}} V_k(X; \overline{X}, \Lambda) = \left[ \frac{\Pi(X)}{\Lambda \Pi(X) - F - I} - \frac{\Pi(X)}{\Lambda \Pi(X) - F} \right] V_k(X; \overline{X}, \Lambda).$$
Single-crossing can be checked as follows. Along any iso-value curve, \( \frac{\partial}{\partial X} V_k(X; \bar{X}, \Lambda) + \frac{\partial}{\partial \Lambda} V_k(X; \bar{X}, \Lambda) \frac{\partial \Lambda}{\partial X} = 0 \). The elasticity of substitution between perceived quality \( \Lambda \) and investment signal \( \bar{X} \) equals
\[
\frac{\partial}{\partial \Lambda} \frac{V_k(X; \bar{X}, \Lambda)}{\partial X} = \frac{\Lambda \Pi(X) - F}{\Lambda \Pi(X) - F - I} - 1.
\]
(B.2)

Expression (B.2) depends positively (and, hence, the elasticity between the competitively required ownership dilution \( \Delta n(X; \Lambda) \) and investment threshold \( \bar{X} \) depends negatively) on the type \( k \) as long as \( f \geq 0 \). That is, the single-crossing property holds:
\[
\frac{\partial}{\partial \Lambda} \left( \frac{\partial}{\partial X} V_k(X; \bar{X}, \Lambda) \right) > 0.
\]
(B.3)

This result can be extended to a broader class of production functions. For a general exercise value, denoted \( v(\Lambda_k, \bar{X}) \), the valuation of type \( k \) when signaling by investing at \( \bar{X} \) and when the perceived type is \( \Lambda \) equals
\[
V_k(X; \bar{X}, \Lambda) = \frac{v(\Lambda_k, \bar{X})}{1 + \Delta n(X; \Lambda)} \left( \frac{X}{\bar{X}} \right)^{\xi} = \frac{v(\Lambda_k, \bar{X})}{v(\Lambda, \bar{X})} \left[ v(\Lambda, \bar{X}) - I \right] \left( \frac{X}{\bar{X}} \right)^{\xi}.
\]
(B.4)

This implies that we have
\[
\frac{\partial}{\partial X} V_k(X; \bar{X}, \Lambda) = \left[ \frac{v_2(\Lambda_k, \bar{X})}{v(\Lambda_k, \bar{X})} - \frac{v_2(\Lambda, \bar{X})}{v(\Lambda, \bar{X})} + \frac{v_2(\Lambda, \bar{X})}{v(\Lambda, \bar{X})} - \xi \frac{1}{\bar{X}} \right] V_k(X; \bar{X}, \Lambda),
\]
\[
\frac{\partial}{\partial \Lambda} V_k(X; \bar{X}, \Lambda) = \left[ \frac{v_1(\Lambda_k, \bar{X})}{v(\Lambda_k, \bar{X})} - \frac{v_1(\Lambda, \bar{X})}{v(\Lambda, \bar{X})} \right] V_k(X; \bar{X}, \Lambda).
\]

Hence, the term
\[
\left( \frac{\partial}{\partial \Lambda} V_k(X; \bar{X}, \Lambda) \right)^{-1} = \left[ \frac{v_2(\Lambda_k, \bar{X})}{v(\Lambda_k, \bar{X})} - \xi \right] \left( \frac{v(\Lambda, \bar{X})}{v(\Lambda_k, \bar{X})} \right) \frac{1}{I} \left[ v(\Lambda, \bar{X}) - I \right] + \frac{v_2(\Lambda, \bar{X})}{v_1(\Lambda, \bar{X})}
\]
depends negatively (and, hence, the elasticity between ownership dilution \( \Delta n(X; \Lambda) \) and investment threshold \( \bar{X} \) depends negatively) on the type \( k \) as long as
\[
\frac{\partial}{\partial \Lambda} \left( \frac{v_2(\Lambda_k, \bar{X})}{v(\Lambda_k, \bar{X})} \right) \leq 0,
\]
or, equivalently,
\[
v(\Lambda_k, \bar{X}) \leq \frac{v_1(\Lambda_k, \bar{X}) v_2(\Lambda_k, \bar{X})}{v_1(\Lambda_k, \bar{X})}.
\]
(B.5)
C Investment timing in the separating equilibrium

The bad type firm is indifferent between mimicking the good type at $X^* \leq X_b$ and waiting to follow its first-best strategy under perfect information if the incentive compatibility constraint (9) holds. After simplifications, this equation can be written as:

$$
\left(\frac{X^*}{X_b}\right)^{\xi} \left[1 - \left(1 - \frac{\Lambda_g}{\Lambda_b}\right) \frac{\xi (F + I) X^*}{\xi (F + I) X^* - (\xi - 1) F X_b} \right] = (1 - \xi) + \xi \left(\frac{\Lambda_g}{\Lambda_b}\right) \left(\frac{X^*}{X_b}\right),
$$

(C.1)

The condition for $X_{\text{min}}$ can be derived analogously. The threshold $X_{\text{min}}$ for which the incentive compatibility constraint (10) is binding represents the lowest value of the cash flow shock such that the good type prefers separation over pooling with the bad type. The threshold $X_{\text{min}}$ satisfies:

$$
\Lambda_g \Pi(X_{\text{min}}) - F - I = \left[\Lambda_g \Pi(X_g) - F - I\right] \left(\frac{X_{\text{min}}}{X_b}\right)^{\xi},
$$
or

$$
\left(\frac{X_{\text{min}}}{X_b}\right)^{\xi} \left[1 - \left(1 - \frac{\Lambda_g}{\Lambda_b}\right) \frac{\xi (F + I)}{\xi (F + I) - (\xi - 1) F} \right] = (1 - \xi) + \xi \left(\frac{\Lambda_g}{\Lambda_b}\right) \left(\frac{X_{\text{min}}}{X_b}\right).
$$

(C.2)

Investment is distorted in the separating equilibrium if at $X_g$ the left-hand side in (9) is larger than the right-hand side, i.e.:

$$
\frac{\Lambda_g \Pi(X_g) - F - I}{\Lambda_g \Pi(X_g) - F} [\Lambda_g \Pi(X_g) - F - I] > [\Lambda_b \Pi(X_b) - F - I] \left(\frac{X_g}{X_b}\right)^{\xi},
$$
or, equivalently, condition (13). From the bad type’s incentive compatibility (9) we have

$$
\Lambda_g \Pi(X^*) - F - I = \left(\frac{\Lambda_b \Pi(X^*) - F}{\Lambda_b \Pi(X^*) - F}\right) \frac{F + I}{\xi - 1} \left(\frac{X^*}{X_b}\right)^{\xi}.
$$

Hence, the market value of each firm before investment satisfies condition (11) for $X < X^*$, and the intrinsic values of the high-type and, respectively, low-type firm before investment are given by:

$$
V_{\text{ics},g}(X) = \begin{cases} 
[\Lambda_g \Pi(X^*) - F - I] \left(\frac{X^*}{X_b}\right)^{\xi} = \left(\frac{\Lambda_b \Pi(X^*) - F}{\Lambda_b \Pi(X^*) - F}\right) \frac{F + I}{\xi - 1} \left(\frac{X^*}{X_b}\right)^{\xi}, & \text{if } X^* < X_g, \\
[\Lambda_g \Pi(X_g) - F - I] \left(\frac{X_g}{X_b}\right)^{\xi} = \left(\frac{\Lambda_b \Pi(X_g)}{\Lambda_b \Pi(X_g)}\right) \frac{F + I}{\xi - 1} \left(\frac{X_g}{X_b}\right)^{\xi}, & \text{otherwise.}
\end{cases}
$$

(C.3)

and

$$
V_{\text{ics},b}(X) = [\Lambda_b \Pi(X_b) - F - I] \left(\frac{X_b}{X_b}\right)^{\xi} = \frac{F + I}{\xi - 1} \left(\frac{X_b}{X_b}\right)^{\xi} = V_b^-(X).
$$
A sufficient condition for $X \in [X_{\text{min}}, X^*]$ to be a Perfect Bayesian equilibrium (PBE) is that the good type has no incentive to deviate to any out-of-equilibrium allocation $\bar{X}$ given some set of out-of-equilibrium beliefs $\Lambda(\bar{X})$:

$$\frac{\Lambda_g \Pi(X) - F - I}{\Lambda_b \Pi(\bar{X}) - F} \geq \max_{X} \frac{\Lambda_g \Pi(\bar{X}) - F}{1 + \Delta n(\Lambda(\bar{X}))(\frac{X}{\bar{X}})^\xi}. \quad (C.4)$$

Value in separating equilibrium \hspace{2cm} Value under defection > 0

The left-hand side of (C.4) is the value under separation at $X$. The right-hand side of (C.4), in turn, is the good type’s value when investing at the threshold $\bar{X}$ and given beliefs $\Lambda(\bar{X})$.

For $X^*$ to constitute a PBE strategy, it suffices to show that condition (C.4) holds under pessimistic beliefs ($\Lambda(\bar{X}) = \Lambda_b \forall \bar{X}$):

$$\Lambda_g \Pi(X^*) - F - I \geq \frac{\Lambda_g \Pi(X) - F}{\Lambda_b \Pi(\bar{X}) - F} \left[ \Lambda_b \Pi(\bar{X}) - F - I \right] \left( \frac{X^*}{\bar{X}} \right)^\xi \quad \text{for all } \bar{X} \geq X^*.$$

From the bad type’s incentive compatibility (9) we have

$$\Lambda_g \Pi(X^*) - F - I = \frac{\Lambda_g \Pi(X^*) - F}{\Lambda_b \Pi(X^*) - F} \left[ \Lambda_b \Pi(X_b) - F - I \right] \left( \frac{X^*}{X_b} \right)^\xi \geq \frac{\Lambda_g \Pi(X^*) - F}{\Lambda_b \Pi(X^*) - F} \left[ \Lambda_b \Pi(X) - F - I \right] \left( \frac{X^*}{X} \right)^\xi \geq \frac{\Lambda_g \Pi(X^*) - F}{\Lambda_b \Pi(X^*) - F} \left[ \Lambda_b \Pi(X) - F - I \right] \left( \frac{X^*}{X} \right)^\xi.$$

The first inequality stems of the optimality of $X_b$, and the second inequality from the fact that $[\Lambda_g \Pi(\bar{X}) - F]/[\Lambda_b \Pi(\bar{X}) - F]$ is decreasing in $\bar{X}$.

**D Investment timing in the pooling equilibrium**

Conditions (17) and (18) can be respectively rewritten as

$$\frac{\Lambda_b \Pi(\bar{X}_{\text{pool}}) - F}{\Lambda_{pool} \Pi(X_{\text{pool}}) - F} \left[ \Lambda_{pool} \Pi(X_{\text{pool}}) - F - I \right] \geq \frac{F + I}{\xi - 1} \left( \frac{X_{\text{pool}}}{X_b} \right)^\xi,$$

and

$$\frac{\Lambda_g \Pi(\bar{X}_{\text{pool}}) - F}{\Lambda_{pool} \Pi(X_{\text{pool}}) - F} \left[ \Lambda_{pool} \Pi(X_{\text{pool}}) - F - I \right] \geq \begin{cases} \left( \frac{\Lambda_g \Pi(X^*) - F}{\Lambda_b \Pi(X^*) - F} \right) \left( \frac{X_{\text{pool}}}{X_b} \right)^\xi, & \text{if } X^* < X_g, \\ \left( \frac{\Lambda_g \Pi(X^*) - F}{\Lambda_b \Pi(X^*) - F} \right) \left( \frac{X_{\text{pool}}}{X_b} \right)^\xi, & \text{otherwise.} \end{cases}$$

Since

$$\Lambda_b \Pi(X_{\text{pool}}) - F \geq \left( \frac{\Lambda_g \Pi(X^*) - F}{\Lambda_g \Pi(X^*) - F} \right) [\Lambda_g \Pi(X_{\text{pool}}) - F],$$

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condition (17) holds whenever condition (18) is satisfied so long as $X_{pool} \geq X^*$ (and $X^* < X_g$). The best pooling equilibrium for a type $k$ firm is one that maximizes the present value of the cash flows accruing to the incumbent shareholders. The objective of management is thus to pick an investment threshold solving the following optimization program:

$$\max_{X_{pool,k}} \left\{ \frac{\Lambda_k \Pi(X_{pool,k}) - F}{\Lambda_{pool} \Pi(X_{pool,k}) - F} \left[ \Lambda_{pool} \Pi(X_{pool,k}) - F - I \right] \left( \frac{X}{X_{pool,k}} \right)^{\xi} \right\}.$$  

The solution to firm $k$'s problem is given by the smooth-pasting condition

$$\frac{\Lambda_k \Pi(X_{pool,k})}{\Lambda_k \Pi(X_{pool,k}) - F} + \frac{\Lambda_{pool} \Pi(X_{pool,k})}{\Lambda_{pool} \Pi(X_{pool,k}) - F - I} - \frac{\Lambda_{pool} \Pi(X_{pool,k})}{\Lambda_{pool} \Pi(X_{pool,k}) - F} = \xi. \quad (D.1)$$

The solution to firm $g$'s problem is given by

$$X_{pool,g} = \frac{\chi_g}{\chi_g - 1} \frac{r - \mu}{\Lambda_{pool}} (F + I), \quad (D.2)$$

with $\chi_g > 0$ as the solution to

$$\chi_g + \frac{F + I}{I + \left[ 1 - \frac{\Lambda_{pool}}{\Lambda_g} \left( \frac{\chi_g - 1}{\chi_g} \right) \right] F} - \frac{F + I}{I \left( 1 + \frac{F}{\chi_g} \right)} = \xi$$

or, equivalently

$$\frac{\chi_g - \xi}{\chi_g \left( \chi_g - 1 \right)} \left( \chi_g + \frac{F}{I} \right)^2 + \left[ \left( \frac{\chi_g - \xi}{\chi_g} \right) \left( \chi_g + \frac{F}{I} \right) - \left( 1 + \frac{F}{I} \right) \right] \left( 1 - \frac{\Lambda_{pool}}{\Lambda_k} \right) \frac{F}{I} = 0. \quad (D.3)$$

A pooling equilibrium, hence, exists if and only if $X^* < X_g$ and condition (18) holds at $X_{pool,g}$ or, equivalently, if the fraction of good projects in the economy, $p$, is large enough that the positive root $\chi_g$ of Eq. (D.3) satisfies

$$I + \left[ 1 - \frac{\Lambda_{pool}}{\Lambda_g} \left( \frac{\chi_g - 1}{\chi_g} \right) \right] F \geq \frac{1}{\xi} \frac{\Lambda_{pool}}{\chi_g} \left( \frac{\xi}{\xi - 1} \right)^{1 - \xi} \left( \Lambda_g \Pi(X^*) - F \right) \left( \Lambda_b \right)^{\xi}. \quad (D.4)$$

Denote by $\bar{p}$ the critical threshold at which (D.4) is binding. Finally, the market value in the pooling equilibrium is related to the intrinsic value of each type as follows:

$$V_{pool}^{-}(X) = p \frac{\Lambda_g \Pi(X_{pool}) - F}{\Lambda_{pool} \Pi(X_{pool}) - F} \left[ \Lambda_{pool} \Pi(X_{pool}) - F - I \right] \left( \frac{X}{X_{pool}} \right)^{\xi} + (1 - p) \frac{\Lambda_b \Pi(X_{pool}) - F}{\Lambda_{pool} \Pi(X_{pool}) - F} \left[ \Lambda_{pool} \Pi(X_{pool}) - F - I \right] \left( \frac{X}{X_{pool}} \right)^{\xi} = \left[ \Lambda_{pool} \Pi(X_{pool}) - F - I \right] \left( \frac{X}{X_{pool}} \right)^{\xi}. \quad (D.5)$$
E Adverse selection and timing constraints

One essential difference between the analysis in this paper and the analysis in Myers and Majluf (MM, 1984) is that MM assume that “the investment opportunity evaporates if the firm does not go ahead at time \( t = 0 \) (pp. 190)”. In the current paper we make the opposite assumption and consider that each firm can delay investment as much as it desires.

To consider intermediate cases, suppose that if the firm does not exercise its investment opportunity promptly, the project can evaporate. Specifically, consider that with some probability \( \lambda dt \) over the time interval \( dt \) the project can disappear because, e.g., the firm’s product becomes obsolete. Under this assumption, the expected time before the project evaporates is given by

\[
\mathbb{E}[T] = \int_0^\infty \lambda t e^{-\lambda t} dt = \frac{1}{\lambda},
\]

(E.1)

showing that as \( \lambda \) tends to infinity, the firm can no longer delay investment.

As before, denote by \( V_k^- \) the value of type \( k \)’s investment project and by \( \Pi(x) \) the present value of a perpetual stream of cash flows \( X \) starting at \( X_0 = x \). Because the firm does not produce any cash flows before investment, the value of the growth option satisfies the following ODE (for \( X < X_k^- \)):

\[
(r + \lambda) V_k^- = \frac{1}{2} \sigma^2 X^2 \frac{\partial^2 V_k^-}{\partial X^2} + \mu X \frac{\partial V_k^-}{\partial X}.
\]

(E.2)

This ordinary differential equation is similar to the one obtained above and incorporates an additional term that reflects the impact of the timing constraint on the value of the project. This term equals \( \lambda(0 - V_k^-) \), since with probability \( \lambda dt \) the value of the investment opportunity will drop from \( V_k^- \) to zero. In the perfect information benchmark, this equation is solved subject to the same no-bubbles, value-matching, and smooth-pasting conditions as before.

Solving the optimization problem of shareholders yields the value of equity in the perfect information benchmark given by:

\[
V_k^- (X) = [\Lambda_k \Pi(X_k^- (\lambda)) - F - I] \left( \frac{X}{X_k^- (\lambda)} \right)^{\beta(\lambda)}.
\]

(E.3)

In this equation, the value-maximizing investment threshold \( X_k^- (\lambda) \) is defined by:

\[
X_k^- (\lambda) = \frac{\beta(\lambda)}{\beta(\lambda) - 1} \frac{r - \mu}{\Lambda_k} (F + I),
\]

(E.4)

where \( \beta(\lambda) = (\sigma^2 - \mu)/\sigma^2 + \sqrt{[(\mu - \sigma^2)/\sigma^2]^2 + 2(r + \lambda)/\sigma^2} \). These expressions are identical to those reported above except that the elasticity \( \beta(\lambda) \) reflects the time constraint imposed on the investment decision. As the hazard rate \( \lambda \) increases, \( \beta(\lambda) \) increases and therefore the investment threshold moves closer to zero.
\[ \beta(\lambda)/(\beta(\lambda) - 1) \] decreases. That is, firms speed up investment as \( \lambda \) increases. In the limit as \( \lambda \to \infty \), the factor \( \beta(\lambda)/(\beta(\lambda) - 1) \) capturing the delay in investment converges to one.

Consider now the limiting case in which \( \lambda \to \infty \). As long as the pooled value exceeds the investment cost, incumbent shareholders can finance the project and keep a positive fraction of the firm’s equity after investment. In particular, using the expression for the number of shares \( \Delta n(X, \Lambda_{\text{pool}}) \) that have to be issued at the time of investment, we have that the value of the claims of the incumbents in the pooling equilibrium is given by:

\[
\frac{\Lambda_k \Pi(X)}{1 + \Delta n(X, \Lambda_{\text{pool}})} = \frac{\Lambda_k \Pi(X)}{\Lambda_{\text{pool}} \Pi(X) - F} \left[ \Lambda_{\text{pool}} \Pi(X) - F - I \right] \quad \text{for } k = g, b.
\] (E.5)

This expression is positive and investment creates value for the old shareholders of the two types of firms as long as the pooled value exceeds the cost of investment (i.e. \( \Lambda_{\text{pool}} \Pi(X) - F > I \)). By contrast if the firms do not invest at time 0, the value of the incumbent’s claims falls to zero as the investment opportunity evaporates. We then have the following result:

**Proposition 6** In the limit as \( \lambda \to \infty \), both types of firms find it profitable to invest as long as the initial value of the cash flow shock satisfies

\[ X_0 > \frac{I + F}{\Pi(\Lambda_{\text{pool}})}. \] (E.6)

In this case it is no longer possible to have a separating equilibrium with equity issuance. Good type reject positive NPV projects for initial values of the cash flow shock satisfying

\[ \frac{I + F}{\Pi(\Lambda_g)} \leq X_0 \leq \frac{I + F}{\Pi(\Lambda_{\text{pool}})}. \] (E.7)

This proposition shows that the model of Myers and Majluf (1984) is nested in ours. In the limit as the firm cannot postpone investment, the option value of waiting to invest vanishes and firms face a now-or-never investment decision. As long as the pooled net present value of the project is positive, both types of firms will want to invest now. For initial values of the cash flow shock satisfying (E.7), the good type will find it profitable to invest while the bad type will want to mimic. The pooled value of the firm is negative, however, and no investor would be willing to provide sufficient funds for investment. This is the standard lemon’s problem in markets with asymmetric information.
F Separation through debt issuance

We denote the values of equity and corporate debt after investment by $E^+_k(X, c)$ and $D^+_k(X, c)$ respectively. Assuming that the firm has issued debt with coupon payment $c$, the cash flow accruing to shareholders after investment over each interval of time of length $dt$ is given by: $(\Lambda_k X - f - c)dt$. In addition to this cash flow, shareholders receive capital gains of $\mathbb{E}[dE^+_k]$ over each time interval. The required rate of return for investing in the firm’s equity is $r$. Applying Itô’s lemma, it is then immediate to show that the value of equity after investment satisfies the following ODE in the region for the cash flow shock where there is no default ($X > X_k(c)$):

$$rE^+_k = \frac{1}{2} \sigma^2 X^2 \frac{\partial^2 E^+_k}{\partial X^2} + \mu X \frac{\partial E^+_k}{\partial X} + \Lambda_k X - f - c.$$  \hspace{1cm} (F.1)

The solution of (F.1) is

$$E^-_k(X, c) = AX\xi + BX\nu + \Lambda_k \Pi(X) - F - \frac{c}{r},$$  \hspace{1cm} (F.2)

where $\xi$ and $\nu$ are the positive and negative roots of the equation $\frac{1}{2} \sigma^2 y(y-1) + \mu y - r = 0$, and $F = f/r$. This ordinary differential equation is solved subject to the following two boundary conditions:

$$\lim_{X \to \infty} \left[ \frac{E^+_k(X, c)}{X} \right] < \infty,$$  \hspace{1cm} (F.3)

$$E^+_k(X, c)\big|_{X=X_k(c)} = 0.$$  \hspace{1cm} (F.4)

The first condition is a standard no-bubble condition implying $A = 0$. The second condition states that equity is worthless in default implying $B = [\Lambda_k \Pi(X(c)) - F - \frac{c}{r}(X(c))^{-\nu}]$. In addition to these two conditions, the value of equity satisfies the smooth-pasting condition: $\partial E^+_k / \partial X \big|_{X=X_k(c)} = 0$ at the endogenous default threshold (see e.g. Leland, 1994, 1998).

Solving this optimization problem yields the following expression for equity value:

$$E^+_k(X, c) = \Lambda_k \Pi(X) - F - \frac{c}{r} - \left[ \Lambda_k \Pi(X) - F - \frac{c}{r} \right] \left( \frac{X}{X_k} \right)^\nu,$$  \hspace{1cm} (F.5)

where the selected default threshold $X_k$ is given by:

$$X_k(c) = \frac{\nu}{\nu - 1} \frac{r - \mu}{\Lambda_k} \left( F + \frac{c}{r} \right).$$  \hspace{1cm} (F.6)

Taking the trigger strategy $X(c)$ as given, the value of corporate debt satisfies in the region for the cash flow shock where there is no default ($X > X_k(c)$):

$$rD^+_k = \frac{1}{2} \sigma^2 X^2 \frac{\partial^2 D^+_k}{\partial X^2} + \mu X \frac{\partial D^+_k}{\partial X} + c.$$  \hspace{1cm} (F.7)
This equation is solved subject to the standard no-bubbles condition \( \lim_{X \to \infty} D_k^+(X, c) = c/r \) and the value-matching condition: \( D_k^+(X, c) |_{X=X_k(c)} = (1 - \alpha) \Pi(X_k(c)) - F \). This condition states that when the firm defaults, the value of corporate debt is equal to the abandonment value of the firm net of default costs. Solving this valuation problem gives the value of corporate debt as:

\[
D_k(X, c) = \frac{c}{r} - \left[ \frac{c}{r} - (1 - \alpha) \Lambda_k \Pi(X_k(c)) + F \right] \left( \frac{X}{X_k(c)} \right)^\nu \\
= \frac{c}{r} - \Lambda_k \nu \left[ 1 - (1 - \alpha) \frac{\nu}{\nu - 1} \right] \left( \frac{c_{pool}}{r} + F \right)^{1-\nu} \left( \frac{\Pi(X)}{\nu} \right)^\nu.
\] (F.8)

Expression (F.8) yields the following useful relation between the debt values: \( \Lambda_k^\nu [D_h(X, c) - \xi] = \Lambda_k^\nu [D_g(X, c) - \xi] \). The value of the firm after investment is now given by \( V_k^+(X, c) = D_k^+(X, c) + E_k^+(X, c) \), or

\[
V_k^+(X, c) = \Lambda_k \left[ \Pi(X) - \alpha \Pi(X_k(c)) \left( \frac{X}{X_k(c)} \right)^\nu \right] - F \\
= \Lambda_k \Pi(X) - F - \eta \left( \frac{c}{r} - D_k(X, c) \right),
\] (F.9)

where the coefficient \( \eta \) is given by (23). The second line in (F.8) and (F.9), respectively, follow from (F.6).

### F.1 Investment timing with debt under symmetric information

Under symmetric information the budget constraint \( D_k(X, c_k(X)) = I \) implies that the coupon \( c_k(X) \) selected by type \( k \) at the time of investment is given by the solution to:

\[
\left( \frac{c_k}{r} + F \right)^{\nu - 1} \left( \frac{c_k}{r} - I \right) = \frac{\alpha}{\eta} \left( \frac{\nu}{\nu - 1} \right) \Lambda_k \Pi(X)^\nu.
\] (F.10)

The credit spread on the debt contract is then given by \( \rho_k(X) = \frac{c_k(X)}{r} / I - 1 \) at the date of issuance. One can now rewrite (F.9) as \( V_k^+(X, c_k(X)) = \Lambda_k \Pi(X) - F - \eta I \rho_k(X) \). The value function of a type \( k \) firm at any time before investment at threshold \( X_{k,D} \) then equals

\[
V_{k,D}^-(X) = [\Lambda_k \Pi(X_{k,D}) - F - I(1 + \eta \rho_k(X_{k,D}))] \left( \frac{X}{X_{k,D}} \right)^\xi.
\] (F.11)

The smooth-pasting condition for the optimal investment threshold \( X_{k,D} \) requires:

\[
\xi [\Lambda_k \Pi(X_{k,D}) - F - I(1 + \eta \rho_k(X_{k,D}))] = \Lambda_k \Pi(X_{k,D}) - \eta I \frac{\partial \rho_k(X_{k,D})}{\partial X_{k,D}} X_{k,D}.
\] (F.12)
In Eq. (F.12), applying the Implicit Function theorem to (F.10) yields

$$\frac{\partial \rho_k(X_{k,D})}{\partial X_{k,D}} = \left( \frac{\nu}{1 + (\nu - 1) \frac{\rho_k(X_{k,D})}{1 + \frac{\rho_k(X_{k,D})}{\rho_k(X_{k,D})}}} \right) \frac{\rho_k(X_{k,D})}{X_{k,D}}.$$

Solving for the investment threshold yields Eq. (24). The value function then equals

$$V_{k,D}^{-}(X) = \left[ \Lambda_k \Pi(X_{k,D}) - \eta I \frac{\partial \rho_k(X_{k,D})}{\partial X_{k,D}} \right] \frac{1}{\xi} \left( \frac{X_{k,D}}{X_{k,D}} \right) \xi \left( \frac{X}{X_{k,D}} \right) \xi = \left[ 1 + \frac{(1 - \nu) \eta \rho_k(X_{k,D})}{1 + \frac{\rho_k(X_{k,D})}{\rho_k(X_{k,D})}} \right] \left( \frac{X_{k,D}}{X_{k,D}} \right) \xi \left( \frac{X}{X_{k,D}} \right) \xi. \tag{F.13}$$

F.2 Incentive compatibility

The critical threshold $X_{D}^{*}$ at which the inventive compatibility constraint (26) of the bad type binds is given by the solution to:

$$V_{b}^{+}(X_{D}^{*}, c_g(X_{D}^{*})) - D_b(X_{D}^{*}, c_g(X_{D}^{*})) = V_{b}^{-}(X_{D}^{*}).$$

Using the expressions for $V_{b}^{+}(X, c_g), D_b(X, c_g),$ and $V_{b}^{-}(X_{D}^{*})$ given in the main text, we can rewrite this equation as

$$\left( \frac{X_{D}}{X_{b}} \right) \xi \left( \frac{X_{D}}{X_{b}} \right) = (1 - \xi) \left[ 1 + \rho_g(X_{D}) I \frac{1 - (1 - \eta)(\frac{\Lambda_b}{\Lambda_g})^\nu}{I + F} \right].$$

The IC condition (27) holds with equality at some threshold $X_{min,D} < X_{g,D}$. For all $X < X_{min,D}$ separation is not a best-response for the good type since the investment distortions required to separate from the bad type are too large compared to the underpricing in a pooling equilibrium. A separating equilibrium in debt exists only if $X_{min,D} \leq X_{D}^{*}$. The critical threshold $X_{min,D}$ at which the inventive compatibility constraint (27) of the good type binds is given by the solution to:

$$V_{g}^{+}(X_{min,D}, c_g(X_{min,D})) - D_g(X_{min,D}, c_g(X_{min,D})) = \frac{\Lambda_g \Pi(X_{b}) - F}{1 + \Delta n(X_{b}; \Lambda_b)} \left( \frac{X_{min,D}}{X_{b}} \right) \xi,$$

which reduces to

$$\left( \frac{X_{min,D}}{X_{b}} \right) \xi \left[ 1 - \left( 1 - \frac{\Lambda_b}{\Lambda_g} \right) \frac{(1 - \xi) F}{\xi I + F} \right] - \xi \left( \frac{X_{min,D}}{X_{b}} \right) = (1 - \xi) \left( \frac{\Lambda_b}{\Lambda_g} \right) \left[ 1 + \rho_g(X_{min,D}) \frac{\eta I}{I + F} \right].$$
F.3 When is debt financing the least-cost separating equilibrium?

The valuations of the good type when separating in debt, separating in equity or pooling in equity are:

Separation in Debt: \[ F + \left( 1 + \frac{1-\alpha}{1+\nu} \rho_k \right) I \left( \frac{X_g}{X_{g,D}} \right) \xi V^{-}(X) = \left( \frac{X_{b}}{X_{g,D}} \right) \xi V^{-}(X). \]

Separation in Equity: 
\[ [\Lambda_{g} \Pi(\bar{X}) - F - I] \left( \frac{X}{\bar{X}} \right) \xi = \left( \frac{\Lambda_{g} \Pi(\bar{X}) - F}{{\Lambda_{b} \Pi(\bar{X}) - F}} \right) V^{-}_{b}(X) \text{ if } \bar{X} < \bar{X}_{g}. \]

\[ [\Lambda_{g} \Pi(\bar{X}_{g}) - F - I] \left( \frac{X}{\bar{X}_{g}} \right) \xi = \left( \frac{\Lambda_{g}}{\Lambda_{b}} \right) \xi V^{-}_{b}(X) \text{ if } \bar{X} \geq \bar{X}_{g}. \]

Pooling in Equity: \[ V^{-}_{pool,g}(X). \]

G Simulation procedure

This appendix describes the procedure used to simulate the panel of firms underlying the analysis of the determinants of investment hazards, financing choices, and costs of external funds.

In all of these analyses, we assume that the economy consists of \( N \) firms. Each firm \( i \) is characterized by the model parameters \( (\Lambda_{g}, \Lambda_{b}, \sigma, \mu, \alpha, F, p) \), which may be firm- or industry-specific. The investment expenditure is normalized to \( I = 100 \). The risk-free rate is assumed to equal \( r = 5\% \). The firms’ own parameters, \( \Lambda_{g}, \sigma, \mu, \alpha \) and \( F \), and the capital market’s beliefs about other firms, \( \Lambda_{b} \) and \( p \), are all allowed to vary, the latter representing differences across industries and varying economic conditions.

We introduce variation across firms by drawing for each firm separate parameters from their natural domains. We also allow for correlation across firms in their respective characteristics. There are several ways in which this can be achieved. For comparability with the numerical analysis in Sections 2 and 3, we opt for perturbations of the base parametrization in Fig. 1 to 4. That is, we start with the base parametrization \( \Lambda_{g} = 1.25, \Lambda_{b} = 1, \mu = .01, \sigma = .25, \alpha = .25, \rho = 10 \) and draw each of the parameters from uniform distributions with the same bounds as in Figures 1 to 5 while keeping the other parameters fixed. The belief \( p \) varies from zero to one in steps of \( 1\% \). We simulate a total of \( N = 60,000 \) firms.

The variables that determine investment and financing strategies in our setting are the firms’ market-to-book ratio, the firms’ growth potential (as measured by \( \Lambda_{g}/\Lambda_{b} \)), cash flow volatility \( \sigma \), cash flow growth \( \mu \), firm size (measured by the natural logarithm of cash flows \( X \)), operating leverage \( F \), default costs \( \alpha \), and the fraction \( p \) of good firms in the industry/economy. We measure the market-to-book ratio either at the time of investment or at the zero-NPV threshold. Firm types are chosen randomly according to the value of \( p \).
References


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Table 1: Adverse Selection and Investment Policy.

The table summarizes the investment and financing behavior of the good and bad firms in each of the three types of equilibrium: separating in equity, pooling in equity, and separating in debt. It also reports the stock price reaction following the announcement of corporate policies.

<table>
<thead>
<tr>
<th>Good type</th>
<th>Bad type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Separation in equity</strong></td>
<td><strong>Separation in debt</strong></td>
</tr>
<tr>
<td>Invests early</td>
<td>Invests optimally</td>
</tr>
<tr>
<td>Positive abnormal returns</td>
<td>Negative abnormal returns</td>
</tr>
<tr>
<td>Issues equity</td>
<td>Issues equity</td>
</tr>
<tr>
<td><strong>Pooling in equity</strong></td>
<td></td>
</tr>
<tr>
<td>Invests late</td>
<td>Invests early</td>
</tr>
<tr>
<td>No announcement returns</td>
<td>No announcement returns</td>
</tr>
<tr>
<td>Issues equity</td>
<td>Issues equity</td>
</tr>
</tbody>
</table>
Table 2: Determinants of Corporate Investment Hazards.

The table documents the determinants of corporate investment, as described by investment hazards (the probability of undertaking the project as a function of time). The table reports the parameter estimates from a linear regression of investment hazards at different points in time ($T = 1, 2, \text{or } 5$) on a set of explanatory variables in simulated data. The three columns in each panel consider different specifications. The marker † next to the coefficient indicates the $p$-value is larger than .001 in a $t$-test of insignificance. The number of observations in each panel is 60,000.

<table>
<thead>
<tr>
<th></th>
<th>T=1</th>
<th>T=2</th>
<th>T=5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market-to-Book</td>
<td>2.19</td>
<td>1.99</td>
<td>1.30</td>
</tr>
<tr>
<td>Cash flow volatility</td>
<td>-0.05</td>
<td>-0.05</td>
<td>-0.01†</td>
</tr>
<tr>
<td>Firm size [ln(\bar{x})]</td>
<td>-0.05†</td>
<td>0.09</td>
<td>-0.77</td>
</tr>
<tr>
<td>Leverage [F]</td>
<td>-0.48</td>
<td>-0.48</td>
<td>0.09</td>
</tr>
<tr>
<td>Cash flow growth [\mu]</td>
<td>-1.40</td>
<td>-1.36</td>
<td>-0.94</td>
</tr>
<tr>
<td>Default cost [\alpha]</td>
<td>-0.00</td>
<td>-0.00</td>
<td>-0.00†</td>
</tr>
<tr>
<td>Growth potential [\Lambda_g/\Lambda_b]</td>
<td>0.01</td>
<td>-0.03</td>
<td>0.00†</td>
</tr>
<tr>
<td>Belief [\beta]</td>
<td>-0.53</td>
<td>-3.52</td>
<td>-2.26</td>
</tr>
<tr>
<td>Interaction terms:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$p \times$ Market-to-Book</td>
<td>-</td>
<td>-</td>
<td>1.99</td>
</tr>
<tr>
<td>$p \times$ Cash flow volatility</td>
<td>-</td>
<td>-</td>
<td>-0.04</td>
</tr>
<tr>
<td>$p \times$ Firm size</td>
<td>-</td>
<td>-</td>
<td>-0.09</td>
</tr>
<tr>
<td>$p \times$ Leverage</td>
<td>-</td>
<td>-</td>
<td>1.59</td>
</tr>
<tr>
<td>$p \times$ Cash flow growth</td>
<td>-</td>
<td>-</td>
<td>-1.29</td>
</tr>
<tr>
<td>$p \times$ Default cost</td>
<td>-</td>
<td>-</td>
<td>-0.96</td>
</tr>
<tr>
<td>$p \times$ Growth potential</td>
<td>-</td>
<td>-</td>
<td>0.00†</td>
</tr>
<tr>
<td>Constant</td>
<td>0.49</td>
<td>0.05†</td>
<td>1.83</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.42</td>
<td>0.41</td>
<td>0.44</td>
</tr>
</tbody>
</table>
Table 3: The Debt-Equity Choice.

The table documents the determinants of the debt-equity financing choice. Panel A reports parameter estimates from a linear discrete choice model for the equity issuance decision in a sample of 60,000 artificial firms simulated from our model. The first column of each specification reports the coefficient estimate, and the second the marginal effect on the choice probability. The marker † next to the coefficient indicates the p-value is larger than .001 in a t-test of insignificance. Panel B documents the in-sample prediction accuracy for this model.


<table>
<thead>
<tr>
<th></th>
<th>Probit (Spec. 1)</th>
<th>Probit (Spec. 2)</th>
<th>Logit (Spec. 1)</th>
<th>Logit (Spec. 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coef.</td>
<td>∂y/∂x</td>
<td>Coef.</td>
<td>∂y/∂x</td>
</tr>
<tr>
<td>Market-to-Book</td>
<td>3.12</td>
<td>0.85</td>
<td>4.58</td>
<td>1.01</td>
</tr>
<tr>
<td>Cash flow volatility</td>
<td>0.13</td>
<td>0.03</td>
<td>0.06</td>
<td>0.01</td>
</tr>
<tr>
<td>Firm size [ln(\overline{X})]</td>
<td>-0.26†</td>
<td>-0.07†</td>
<td>-1.00</td>
<td>-0.22</td>
</tr>
<tr>
<td>Leverage [F]</td>
<td>1.01</td>
<td>0.27</td>
<td>0.54</td>
<td>0.12</td>
</tr>
<tr>
<td>Cash flow growth [\mu]</td>
<td>-2.31</td>
<td>-0.63</td>
<td>-2.70</td>
<td>-0.60</td>
</tr>
<tr>
<td>Default cost [\alpha]</td>
<td>0.20</td>
<td>0.05</td>
<td>0.16</td>
<td>0.04</td>
</tr>
<tr>
<td>Growth potential [\lambda_g/\lambda_b]</td>
<td>4.32</td>
<td>1.18</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Belief [p]</td>
<td>2.35</td>
<td>0.64</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Interaction terms:

- \(p \times \) Market-to-Book
- \(p \times \) Cash flow volatility
- \(p \times \) Firm size
- \(p \times \) Leverage
- \(p \times \) Cash flow growth
- \(p \times \) Default cost
- \(p \times \) Growth potential

\(R^2\) 0.70 0.54 0.69 0.81

Panel B: Predictive Accuracy.

<table>
<thead>
<tr>
<th></th>
<th>Probit (Spec. 1)</th>
<th>Probit (Spec. 2)</th>
<th>Logit (Spec. 1)</th>
<th>Logit (Spec. 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observed Decision</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Debt</td>
<td>0.93</td>
<td>0.07</td>
<td>0.82</td>
<td>0.18</td>
</tr>
<tr>
<td>Equity</td>
<td>0.11</td>
<td>0.89</td>
<td>0.05</td>
<td>0.95</td>
</tr>
</tbody>
</table>

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Table 4: Additional Empirical Predictions of the Model.

The table summarizes the predictions of the model for the relation between informational asymmetries and the cost of external funds, firms’s financing strategies, abnormal announcement returns, and the probability of ex-post losses. In the table, a + sign indicates that the variable of the corresponding raw has a positive first derivative with respect to the parameter in the corresponding column. The marker ⋆ next to the sign indicates the prediction is unique to our theory.

<table>
<thead>
<tr>
<th></th>
<th>Val. uncertainty</th>
<th>Oper. leverage</th>
<th>Volatility</th>
<th>Growth rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>External financing costs</td>
<td>+/–⋆</td>
<td>=/–⋆</td>
<td>+/–</td>
<td>–</td>
</tr>
<tr>
<td>Financial leverage</td>
<td>–⋆</td>
<td>–</td>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>Abnormal announcement returns</td>
<td>+</td>
<td>+⋆</td>
<td>–⋆</td>
<td>–</td>
</tr>
<tr>
<td>Probability of ex post losses</td>
<td>–⋆</td>
<td>–⋆</td>
<td>+⋆</td>
<td>–</td>
</tr>
</tbody>
</table>

Table 5: Determinants of External Financing Cost.

The table summarizes the determinants of external financing costs in the model. Reported are the coefficients from an ordinary least-squares regression of a cost measure on observable characteristics and structural parameters. The dependent variable is the cost of external funding measured in per cent of first-best (option) value. The cost measure is evaluated in present value terms at the 0-NPV threshold and given by Cost (%) = 100 * (V_g^- - max(V_{pool, g}, V_{lcs, g}, V_{D, g}))/V_g^- . The p-value in a t-test of insignificance is smaller than .001 for each of the coefficients reported. The number of observations in each panel is 60,000.

<table>
<thead>
<tr>
<th></th>
<th>Specification 1</th>
<th>Specification 2</th>
<th>Specification 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market-to-Book</td>
<td>3.82</td>
<td>2.88</td>
<td>5.23</td>
</tr>
<tr>
<td>Cash flow volatility [σ]</td>
<td>-0.13</td>
<td>-0.12</td>
<td>-0.18</td>
</tr>
<tr>
<td>Firm size [ln(X)]</td>
<td>0.32</td>
<td>0.52</td>
<td>0.47</td>
</tr>
<tr>
<td>Leverage [F]</td>
<td>-1.62</td>
<td>-1.60</td>
<td>-2.03</td>
</tr>
<tr>
<td>Cash flow growth [μ]</td>
<td>-1.66</td>
<td>-1.55</td>
<td>-2.45</td>
</tr>
<tr>
<td>Default cost [α]</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Growth potential [λ_g/λ_b]</td>
<td>-0.01</td>
<td>–</td>
<td>0.03</td>
</tr>
<tr>
<td>Belief [p]</td>
<td>-2.78</td>
<td>–</td>
<td>-1.23</td>
</tr>
<tr>
<td>Interaction terms:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p × Market-to-Book</td>
<td>–</td>
<td>–</td>
<td>-3.94</td>
</tr>
<tr>
<td>p × Cash flow volatility</td>
<td>–</td>
<td>–</td>
<td>0.12</td>
</tr>
<tr>
<td>p × Firm size</td>
<td>–</td>
<td>–</td>
<td>-0.23</td>
</tr>
<tr>
<td>p × Leverage</td>
<td>–</td>
<td>–</td>
<td>1.17</td>
</tr>
<tr>
<td>p × Cash flow growth</td>
<td>–</td>
<td>–</td>
<td>1.81</td>
</tr>
<tr>
<td>p × Default cost</td>
<td>–</td>
<td>–</td>
<td>-0.01</td>
</tr>
<tr>
<td>p × Growth potential</td>
<td>–</td>
<td>–</td>
<td>-0.08</td>
</tr>
<tr>
<td>Constant</td>
<td>2.69</td>
<td>4.09</td>
<td>2.20</td>
</tr>
<tr>
<td>R²</td>
<td>0.81</td>
<td>0.66</td>
<td>0.88</td>
</tr>
</tbody>
</table>
Figure 1: EQUITY SEPARATING EQUILIBRIUM.

Panel A plots the investment threshold in the equity separating equilibrium (bold line), the first-best investment threshold (solid blue line), and the 0-NPV threshold (dashed green line) for the high-type firm. Panel B plots the external financing costs under equity financing and separation for different parameter values. The value loss is measured by the drop in firm value due to investment distortions in per cent of first-best (option) value. Panel C plots the abnormal announcement returns under equity financing and separation for different parameter values. Depicted is the rise in the stock price for high-type firms (solid blue line) and the drop for low-type firms (dashed red line) at the separating investment threshold. The base parametrization is \( p = .5, \Lambda_g = 1.25, \Lambda_b = 1, r = .05, \mu = .01, \sigma = .25, I = 100, F = 10/r. \)

Panel A: Investment threshold.

Panel B: External financing costs \( (V_g^- - V^-_{lcs, g}) / V^-_g \).

Panel C: Announcement returns \( (V^+_k - V^-_{lcs}) / V^-_{lcs} \).
Figure 2: LEAST-COST EQUITY EQUILIBRIUM.

The different panels plot the least-cost equity equilibrium, investment threshold, and external financing costs under equity financing for different parameter values. Panel A depicts the least-cost equilibrium as a function of the parameters $\Lambda_g$, $\Lambda_b$, $\mu$, $\sigma$, $F$, and $r$ on the x-axis and of investors' beliefs about the fraction of high-type firms $p$ on the y-axis. Panel B depicts the investment threshold in the least-cost equity equilibrium (bold line), the first-best investment threshold (solid blue line), and the 0-NPV threshold (dashed green line). Panel C depicts the drop in firm value due to investment distortions in the least-cost equity equilibrium for different parameter values. The value loss is evaluated at the 0-NPV threshold, measured in per cent of first-best (option) value, and given by Cost (%) = $(V_g^\ominus - \max(V_{\text{pool},g}^\ominus, V_{\text{lcs},g}^\ominus))/V_g^\ominus$. Panel D depicts the underpricing of the shares issued in the pareto-dominant pooling equilibrium for different parameter values. The underpricing is measured in per cent and given by Underpricing (%) = $(V_g^{\ominus} - V_{\text{pool}}^{\ominus})/V_{\text{pool}}^{\ominus}$ at the issuance date. The base parametrization is $p = .5$, $\Lambda_g = 1.25$, $\Lambda_b = 1$, $r = .05$, $\mu = .01$, $\sigma = .25$, $I = 100$, $F = 10/r$.

Panel A: Least-cost equity equilibrium.
Figure 2: Least-Cost Equity Equilibrium—continued.

Panel B: Investment threshold.

Panel C: External financing costs.

Panel D: Underpricing.
Figure 3: LEAST-COST EQUILIBRIUM WITH DEBT.

The different panels plot the least-cost equilibrium, investment threshold, external financing costs, and abnormal announcement returns in the least-cost equilibrium for different parameter values. Panel A depicts the least-cost equilibrium as a function of the parameters $\Lambda_b$, $\Lambda_g$, $\mu$, $\sigma$, $F$, and $\alpha$ on the x-axis and of investors’ beliefs about the fraction of high-type firms $p$ on the y-axis. Panel B depicts the investment threshold in the least-cost equilibrium (bold line), the first-best investment threshold (solid blue line), and the 0-NPV threshold (dashed green line). Panel C plots the announcement returns in the least-cost equilibrium for different parameter values. Depicted is the rise in the stock price for high-type firms (solid blue line) and the drop for low-type firms (dashed red line) at the (equity or debt) separating investment threshold. Abnormal announcement returns are given by $AR_k(\%) = \frac{(V_k(X) - D_k(X))}{\max(V_{lcs,D}(X), V_{lcs}(X))} - 1$ for $k = g, b$ at $X = \bar{X} \wedge \bar{X}_g$ if equity separation is least-cost and at $X = \bar{X}_{g,D}$ if debt separation is least-cost. Panel D depicts the drop in firm value due to investment distortions in the least-cost equilibrium for different parameter values. The value loss is evaluated at the 0-NPV threshold, measured in per cent of first-best (option) value, and given by Cost (%) = $(V_g - \max(V_{pool,g}, V_{lcs,g}, V_{g,D})) / V_g$. The base parametrization is $p = .5$, $\Lambda_g = 1.25$, $\Lambda_b = 1$, $r = .05$, $\mu = .01$, $\sigma = .25$, $\alpha = .25$, $I = 100$, $F = 10/r$.

Panel A: Least-cost equilibrium.
Figure 3: LEAST-COST EQUILIBRIUM WITH DEBT—CONTINUED.

Panel B: Investment threshold.

Panel C: Announcement returns.
Figure 3: Least-Cost Equilibrium with Debt—continued.

Panel D: External financing costs.
Figure 4: Investment Probability.

The figure plots the probability of investment as a function of time under adverse selection in comparison with the probability of investment under the first-best investment policy (dashed line). We compute this probability when the firms separate (good type: solid line, bad type: dotted line) and when the firms pool (dash-dotted line). The top chart in each panel plots the cumulative probability of investment $F(t)$ given in expression (30), and the bottom chart the hazard rate $F'(t)/(1 - F(t))$. Input parameter values are set as in the base case environment with the fraction of good projects given by $p = .5$ in the separating equilibrium and by $p = .7$ in the pooling equilibrium. The initial value of the cash flow shock, $X_0$, is set to $x$ times the 0-NPV threshold, and we vary $x$ across panels. The base parametrization is $\Lambda_g = 1.25$, $\Lambda_b = 1$, $r = .05$, $\mu = .01$, $\sigma = .25$, $I = 100$, $F = 10/r$.

Panel A: $X_0 = 2\bar{X}_g^0$.  
Panel B: $X_0 = 1.5\bar{X}_g^0$.  
Panel C: $X_0 = \bar{X}_g^0$. 

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Figure 5: Announcement Returns and Ex-Post Losses.

Panel A plots the loss probability under equity financing and separation for different parameter values. Depicted are the loss probabilities in the equity separating equilibrium for the high-type firm (solid line) and under the first-best investment policy (dashed line). The loss probability is measured by the likelihood that the asset value falls below the investment cost at some time over the next 5 years and is given by expression (31). Panel B plots the abnormal announcement returns under equity financing and separation against the loss probability for different parameter values. The horizontal axis measures the rise in the stock price for high-type firms at the separating investment threshold. The base parametrization is \( p = .5, \Lambda_g = 1.25, \Lambda_b = 1, r = .05, \mu = .01, \sigma = .25, I = 100, F = 10/r \). We focus on environments in which firms separate by issuing equity.


Panel B: Announcement returns \((V_k^+ - V^-_{lcs})/V^-_{lcs}\) and probability of ex-post losses.