Strategic Interaction and the Co-Determination of Firms' Financial Policies

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Job Market Paper

February 3, 2007

Abstract

With a few notable exceptions, corporate finance studies of firms' financial policies typically rely on a single firm setting, thus overlooking the possibility that firms' financial policies are co-determined by those of their rivals. I develop and test a model in which firms interact by buying and selling productive assets. This interaction affects cash policies because a lack of cash may force a firm to sell assets at a discount, while having surplus cash may enable a firm to take advantage of other firms' asset sales. The model generates sharp and novel empirical predictions at the industry (as opposed to the individual firm) level. I test these predictions using a carefully built methodology that tackles the endogeneity and persistence of firm-level determinants. Precisely as predicted by the theory, I find that both the average cash holdings in an industry, as well as the heterogeneity in cash policies within that industry, depend on two variables: the asset specificity of that industry and industry cashflow volatility. These results point to the importance of strategic interaction as a determinant of corporate financial policies.

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1 Introduction

Most of the corporate finance literature uses a single-firm framework to analyze a firm's decision making process[1]. This framework ignores strategic interactions among firms, thus overlooking the potentially important feature that firms' financial policies are co-determined by those of their rivals. I develop and test a model of joint determination of financial policies in which firms interact by buying and selling productive assets.

A central aim of corporate financial policy is to provide future financial flexibility, a point stressed by managers surveyed by Graham and Harvey (2001). One policy particularly associated with the concept of flexibility is the management of cash holdings. I offer an equilibrium model of cash holdings where firms interact by buying and selling assets, and find flexibility important because external funds may be more costly in the future. Since internal cash reserves and asset sales are alternative sources of funding, the price of assets affects the benefits of carrying cash. The price of assets is determined by the supply and demand for productive assets, which are, in turn, a function of potential buyers' and sellers' cash holdings. Therefore, optimal cash policies are interdependent. This theory generates sharp and novel predictions about *industry* patterns in cash holdings. Crucially, the unit of analysis shifts from the *individual* firm of the single-firm framework, to the *industry* as a whole. In equilibrium, the model shows that both average cash holdings in an industry, as well as the heterogeneity in cash policies within that industry, depend on two variables: the asset specificity of that industry, and industry cashflow volatility.

I carry out a detailed empirical analysis of the model's predictions concerning industry-wide patterns in cash holdings. The tests are performed after accounting for effects unrelated to firm interaction by using a carefully developed methodology that tackles the endogeneity and persistence of some determinants. Precisely as the theory predicts, I find that average cash in an industry depends on that industry's asset specificity, industry cashflow volatility, and their arithmetic product. The theory about heterogeneity in cash policies within an industry is strongly backed by the data as well. All the effects are found to be statistically and economically significant. Additional evidence from mergers and acquisitions shows that asset specificity affects average levels of industry cash via asset sales.

After this quick overview of the main plot, let me elaborate on both the theoretical and empirical investigation.

To understand in greater depth the theory of how strategic interaction influences optimal cash policies, consider a scenario where, in the spirit of Keynes (1936), firms carry cash both

[1]One exception is the literature on the effects of product market competition. See, e.g., Brander and Lewis (1986), Maksimovic and Titman (1991), Chevalier and Scharfstein (1995), Adam, Dasgupta, and Titman (2006), Kovenock and Phillips (1997), Campello (2003), and the discussion below.

to lower the likelihood of forced asset liquidations because of financial distress and to be able to buy assets of other firms that may be distressed. In the presence of market frictions that limit access to outside financing, lack of cash may force a firm into distress sales of its assets, while having surplus cash may enable a firm to take advantage of another firm's distressed sales instead. Ultimately, however, the costs of financial distress and the return on investments that a firm obtains by buying other firms' assets both depend on the price of those assets. A high price reduces the costs of financial distress and also reduces the return for a firm buying distressed assets, thus reducing the incentives to carry cash. Similarly, a low price increases the incentives to carry cash. But the price itself is endogenous and depends on supply and demand, which means that it depends on the cash holdings of all the firms in the industry.

In addition, the price of assets—and thus, the incentives for a firm to hold cash—may be affected by potential demand for assets from outside the industry. This demand depends on how "specific" the assets are in the sense of Williamson (1985) and Shleifer and Vishny (1992). The lower the degree of specificity of an industry's assets, the greater the number of potential outside buyers, and the lower the incentive to carry cash. Thus, in equilibrium, the average cash in an industry increases with that industry's asset specificity.

The cash available to a firm depends on cash reserves carried over from the previous period, as well as on current cashflow from operations. Further, since industry-wide shocks to cashflow affect all firms in the industry in the same fashion, the price of productive assets increases with industry-wide shocks. However, the effects of the future industry cashflow shocks on *ex-ante* incentives to carry cash are complex. An increase in industry cashflow volatility leads to an increase in the average size of both positive and negative shocks, which increases prices in industry upturns and decreases them in downturns. The overall impact of the change in volatility on the incentives to carry cash depends on the relative strengths of these two opposing effects. However, one of the two depends much more on asset specificity than the other—the lower is the valuation of assets to outsiders, the lower the prices can go in downturns. Given an increase in industry cashflow volatility, the higher the asset specificity is, the higher are the *ex-ante* benefits of carrying cash. Thus, in equilibrium, the average cash level in an industry increases in the arithmetic product between asset specificity and industry cashflow volatility.

A second key set of results stems from the fact that firms from the same industry choose, in some settings, to carry different amounts of cash, even though they are *ex-ante* identical. To understand why, start by assuming that firms follow a similar cash policy and there is an important common component in cashflow, making firms likely to survive or default together. Due to similar cash policies and cashflows, a firm choosing to carry less cash defaults not only in the states in which all other firms in an industry default, but also in some states when all other firms survive. Yet, the surviving firms' resources insure that default in the latter case is costless for the firm and that survival generates no benefit from buying cheap assets. Hence, the low-cash firm is better off than all others, since it saves the cost of carrying cash without incurring an increase in default costs, nor a loss of investment opportunities.

In equilibrium, identical firms separate into two basic groups—those that carry high levels of cash and those that carry lower levels. This heterogeneity in cash policies acts as a hedge for firms against the common fate of either default or survival that would be induced by the commonality of cashflow in that industry. Additionally, as the valuation to outsiders decreases, the disincentives to survive or default together are stronger, and firms find greater benefit from carrying different levels of cash. Hence, the variability of cash policies within an industry increases with industry cashflow volatility and with industry asset specificity.

I test the empirical predictions of my theory to provide evidence about the effects of firms' interaction on their financial structures. In order to prove the presence of the effects, the patterns in firm financial structure should be observable after accounting for the determinants predicted by theoretical models that lack the interaction feature. To account for these other determinants, I consider a dynamic model of cash that includes these determinants along a set of industry dummies.

The estimation poses several econometric challenges. The endogeneity of the common cash determinants (capital expenditures, leverage, etc.), combined with the presence of lag cash, renders the standard ordinary least squares (OLS), fixed effects, or Fama-Macbeth approaches inappropriate.[2] To overcome these challenges, I estimate the model using a two-step dynamic panel data methodology based on Anderson and Hsiao (1982) and Arellano and Bond (1991). First, I consistently estimate the coefficients on the time-varying endogenous variables using a first difference approach coupled with instrumentation with their lags. Second, I estimate the coefficients on time-invariant variables (including, importantly, the industry dummies) through an OLS regression of the first-step errors on the respective variables.

The industry dummies play an important role in the actual tests of the interaction theory. Since the theory relates cash to two industry-level variables, the industry dummies should capture, among others, any empirical effects of the theory that are unexplained by control variables. In order to test the hypotheses about patterns in industry averages of cash, I use the set of dummy coefficients as the dependent variable in a cross-sectional regression on asset specificity, cashflow volatility, and their arithmetic product.

To measure asset specificity, I use three accounting-based proxies. While Williamson (1988) argues for the development of better measures of asset specificity than the accounting-based ones, that challenge is beyond the scope of this article. The motivation for employing the first

[2]See William Greene notes at http://pages.stern.nyu.edu/~wgreene/Econometrics/PanelDataEconometrics.htm and Jennifer Smith notes at http://www2.warwick.ac.uk/fac/soc/economics/staff/faculty/jennifersmith/panel/

measure comes from Maksimovic and Phillips (2001), who show that firms do not branch into industries in which they cannot efficiently use their assets. Therefore, industries where there are more single-segment firms have higher asset specificity. The second and third measures capture the idea that, of all assets operated by a firm, intangibles are the hardest to value, are the most difficult for firms from other industries to understand, and the most challenging to integrate with processes in other industries.

I find that the behavior of average industry cash holdings is positively related to asset specificity, as theorized. When cashflow volatility is at its mean, the marginal increase in cash holdings generated by a one standard-deviation increase in asset specificity is around 2.5% of asset value. This effect is comparable to the median firm cash holdings of 6.7%. The product of asset specificity and cashflow volatility is significant for two out of three measures. In these cases, a one-standard-deviation increase in both asset specificity and cashflow volatility leads to a 1% increase in industry cash due to the interaction term.

Moreover, the explanatory power of the model is significant. While lag cash and firm-specific variables explain 11% of cash variation, the effects due to firm interaction explain approximately one-quarter of what the interaction-unrelated variables explain. This is particularly noteworthy, given that asset specificity and cashflow volatility are measured at the industry level and, thus, so much more coarsely than the firm-year level for the other determinants.

The second set of tests concerns the effects of the interaction on the intra-industry variability in cash. The tests are based on a measure of intra-industry variability that is constructed as the difference between the top and bottom quintiles of within-industry residuals from the empirical model. The test consists of regressing this range measurement on asset specificity and industry cashflow volatility.

The hypothesis about the intra-industry variability in cash is strongly confirmed in all tests. A one standard-deviation increase in asset specificity leads to an absolute increase of 5% in the difference between the first- and fifth-quintile cash-to-net assets ratio, while a one standard-deviation increase in cashflow volatility leads to a 3% increase in the same difference. The model explains almost half of the variation across industries in the range of cash level between an industry's top and bottom firms. The confirmation of this hypothesis, which is natural only to a framework with interaction among firms, strongly supports the case for the joint determination of firm financial policies based on their interaction.

Even though the theory is presented in terms of cash and it abstracts from the choice of debt policies, firms employ cash and debt capacity for similar purposes. Thus, similar arguments can be made about optimal debt capacity given interaction among firms. Empirically, I expect that industry net debt is negatively related to asset specificity and to its arithmetic product with industry cashflow volatility. Moreover, the intra-industry variability in net debt should be positively related to asset specificity and to industry cashflow volatility.

The effect of asset specificity on industry net debt is twice as strong as its effect on cash. The results show that the interaction among firms has a strong effect not only on cash but on debt as well. These results contrast partially with Benmelech (2005), who uses a sample of railroads to show that asset salability affects debt maturities, but not debt levels.

My theoretical model provides additional predictions about the market for productive assets. Using mergers and acquisitions data, I test some of these predictions across industries. Consistent with my theory, I find that, for sales to firms from the same industry, the decrease in the price-to-book value of the target from industry upturns versus downturns is positively related to the industry's asset specificity. In addition, the average cash in an industry is a function of this decrease in price-to-book, but its explanatory power disappears when asset specificity and industry cashflow volatility are added to the model. These results show that the link between cash and the decrease in price-to-book exists because both depend on asset specificity.

A driving assumption of my theoretical framework is the existence of external financing constraints. Absent these constraints, there are clearly no incentives for a firm to hold cash. In the theoretical literature, there have been efforts to derive the existence of constraints in an incomplete-contracting framework (see, e.g., Hart and Moore (1994), Holmstrom and Tirole (1997)). The empirical case for their existence and for their effect on firm financial and investment policies is much stronger, and it has been recently documented by, among others, Almeida, Campello, and Weisbach (2004), Rauh (2006), and Faulkender and Petersen (2006). See Hubbard (1998) for a review of the earlier literature.

The above theoretical framework follows the intuition of Shleifer and Vishny (1992)'s treatment of optimal leverage in the presence of interaction between two firms. I enrich their framework to include a continuum of firms and normally distributed—and possibly correlated—cashflows. This richer structure generates a more complex equilibrium. I am able to characterize the equilibrium extensively, which allows me, in contrast to Shleifer and Vishny (1992), to derive sharp and novel empirical predictions about what patterns should be observed in optimal financial structures due to strategic interaction.

Some of the predictions of Shleifer and Vishny (1992) about the types of buyers and sellers of assets, and about prices are tested by Pulvino (1998). He shows that in the airline industry, during downturns, outsiders are more likely to buy assets, and prices are lower than in normal times. Moreover, Acharya, Bharath, and Srinivasan (2006) show that during industry downturns, bond recovery rates depend on the asset specificity of the industry.

My paper is also related to the literature on asset sales. Berger, Ofek, and Swary (1996) show that, out of all assets, long-term assets are sold for the deepest discount relative to their book value. The interaction among firms in the market for productive assets has been extensively analyzed theoretically and empirically in Maksimovic and Phillips (2001, 2002).

Other studies on asset sales are referenced in these articles.

Another strand of literature on the interdependence of financial policies considers interactions via product markets. A partial list of theoretical work includes Brander and Lewis (1986), Maksimovic (1988), Maksimovic and Titman (1991), Bolton and Scharfstein (1990), and Chevalier and Scharfstein (1995). Recently, Adam, Dasgupta, and Titman (2006) explain what industry-wide patterns in hedging decisions are generated by strategic interaction. In the same vein as De Meza (1986) and Maksimovic and Zechner (1991), their study shows that similar firms may optimally pursue different policies when firms' actions are jointly determined. Empirical tests have been carried out, among others, by Chevalier (1995), Phillips (1995), Kovenock and Phillips (1997), and Campello (2003).

The literature on the determinants of cash in a non-interaction framework includes theoretical works by Baumol (1952) and Miller and Orr (1966), and recently by Kim, Mauer, and Sherman (1998). Extensive evidence on the firm-level determinants of cash is presented by Opler, Pinkowitz, Stulz, and Williamson (1999). Other cash holdings explanations tested are: taxes (Hartzell, Titman, and Twite (2006)), corporate governance (Dittmar, Mahrt-Smith, and Servaes (2003), Harford, Mansi, and Maxwell (2005), Kalcheva and Lins (2005), and Pinkowitz, Stulz, and Williamson (2006)), and free cashflow (Harford (1999)). Froot, Scharfstein, and Stein (1993) consider the theoretical effects of costly external financing on a more general set of policies associated with financial flexibility. Acharya, Almeida, and Campello (2005) explore the joint determination of cash and debt policies. Other recent works pertaining to cash policies are Mikkelson and Partch (2003), Faleye (2004), Bates (2005), Dittmar and Mahrt-Smith (2007), and Faulkender and Wang (2006).

The paper proceeds as follows: section 2 presents the theory, section 3 deals with data issues, section 4 presents the empirical evidence, and section 5 concludes.

2 Theory

I consider a two-period financing and investing model where agents from an industry carry cash both to avoid distress and to buy the assets of firms that are distressed. Each agent has one unit of a productive asset that generates cashflows each period. The random intermediate cashflow, together with the cash carried over, determine whether the firm survives or must sell its assets. Prospective buyers are either surviving firms or firms from outside the industry, with the latter having a lower valuation of assets than the former. The price of assets is determined by supply and demand. Each firm chooses how much cash to hold such that it maximizes firm value given the cash holdings policies of the other firms.

This framework may potentially generate both symmetric and asymmetric equilibria. Therefore the issues of equilibrium existence and uniqueness become non-trivial. Further, any set of empirical predictions must hold over a wide range of settings, and these settings may result in different types of equilibrium.

2.1 Setup

The industry consists of a continuum of identical firms with measure one. Each industry insider $\alpha \in [0, 1]$ is endowed with one unit of a productive asset, infinitely divisible, that generates cashflows at $t = 1$ and 2. At $t = 0$ all units of the asset are owned by insiders.

For each α, the cashflow at $t = 1$ (F_α) is random and has 3 components: mean μ, an industry-wide, systematic component $\sigma_y z$, and a firm specific, idiosyncratic component $\sigma_x z_\alpha$, where z is independent of z_α, and z_α is independent across α.

$$F_\alpha = \mu + \sigma_y z + \sigma_x z_\alpha \text{ where } z, z_\alpha \sim IIDN[0, 1]$$

The systematic cashflow volatility is given by σ_y and the idiosyncratic volatility by σ_x. Therefore, the volatility of industry cashflow is σ_y and the correlation between a firm's cashflow and industry cashflow is $\sqrt{\sigma_y^2/(\sigma_y^2 + \sigma_x^2)}$. Further, if at $t = 0$ insiders have debt D_1 due at $t = 1$, then without loss of generality, we may replace μ by $\mu - D_1$ and assume that short-term debt is 0.

At time 2, the asset pays 1 if it is used by an inside firm, or $L < 1$ if it is used by outside firms. The cashflow at $t = 2$ introduces the valuation differential between an insider and an outsider, namely the "specificity" of the asset. The lower L is, the higher the asset specificity in that industry. Since all firms in the industry have a similar asset, asset specificity is an industry-level characteristic.

Insiders decide to hold cash c from $t = 0$ to $t = 1$, which is either raised from risk-neutral investors or carried over from previous periods. Carrying cash c has a cost of $\xi(c) = \xi c^2/2$ for the firm. The cost may arise from managers' investing in negative NPV projects.

Various frictions make external financing impossible or unreliable and carrying cash attractive. While in my model I assume the external financing restrictions, there have been theoretical efforts to justify them in incomplete contracting frameworks. For example, Hart and Moore (1994) show that due to the inalienability of human capital, firms cannot realistically pledge more than the liquidation value of a project. Otherwise, the entrepreneur may threaten to withdraw his human capital and renegotiate the payments. Moreover, the model of moral hazard in project choice of Holmstrom and Tirole (1997) implies limited pledgeability. When project choice cannot be specified contractually, entrepreneurs have to get a high enough fraction of cashflows to induce them to choose the most profitable project. Lastly, Gertner, Scharfstein, and Stein (1994) show that when cashflows are not verifiable, firms may prefer internal financing to external one.

Empirically, there is significant evidence that these constraints exist and they have a strong impact on the firm financial and investment policies. An additional justification comes from Servaes and Tufano (2006): the CFOs they survey mention concerns about the availability of external financing when needed as one of the main reasons to hold cash.

I incorporate external frictions in my model by restricting insiders' access to external financing at $t = 1$. The worse the industry shock is, the more this restriction affects a firm investment capacity. This is comforting, since the main theoretical justifications for financing constraints are more natural to industry down states: high asymmetric information between investors and managers, or managers engaging in asset substitution.

A possible way to endogenize the financing restrictions is to allow firms to pledge only the liquidation value of assets. Casted in a multi-period framework, this mechanism strengthens the constraints via a multiplier effect, as in Kiyotaki and Moore (1997).

The assumption that even insiders with a positive amount of cash are restricted may be too harsh. I relax this assumption in Appendix A by allowing project financing, or partial pledgeability of newly acquired assets.

Given the financing constraints, at $t = 1$ insiders default if the cash retained from $t = 0$ and the period's cashflows are not enough to meet firm's obligations: $F + c < 0$. When firms default, their assets are sold at a uniform price auction. There are two types of buyers for the assets: surviving insiders and outsiders. Insiders can use only the cash on hand $(F + c)$ to buy distressed assets due to external financing constraints. The outsiders are assumed to be numerous, thus even though each one may be partially constrained, as a group they always have enough resources to pay their reservation value L for any amount of assets.

Since firms are identical *ex ante*, I start by investigating symmetric equilibria. A symmetric equilibrium is a set $\{c, p(\mathcal{F}_1)\}$, where c is the time 0 cash policy of all firms and $p(\mathcal{F}_1)$ is the time 1 distressed assets pricing functional. An insider firm must attain its maximum value at time 0 when it holds c in cash, given that all other firms in the industry hold c in cash and prices at time 1 are given by p. Price p must be such that markets clear at $t = 1$, given the realization of $t = 1$ cashflows and that all firms in the industry save c in cash.

2.2 Solution

I proceed by deriving the form of the pricing functional and the firm's objective function, allowing for the existence of asymmetric equilibria. I obtain a closed-form expression for first-order condition (FOC), but I must solve it numerically.

Prices

Lemma 1. *Let insider α have cash c^1_α at $t = 1$. Let $\bar{c}^1 = \int_\alpha 1_{c^1_\alpha \geq 0} c^1_\alpha d\alpha$ be the total cash available to surviving insiders. The aggregate demand function is:*

$$D(p) = \begin{cases} 0 & \text{if } p > 1 \\ [0,\, \bar{c}^1] & \text{if } p = 1 \\ \bar{c}^1/p & \text{if } L < p < 1 \\ [\bar{c}^1/L,\, \infty) & \text{if } p = L \\ \infty & \text{if } p < L \end{cases} \tag{1}$$

The aggregate supply does not depend on p and is given by $S = \int_\alpha 1_{c^1_\alpha \leq 0} d\alpha$

Lemma 1 gives the form of the demand and supply. Each buyer bids as long as the price is less or equal to the $t = 2$ cashflow it receives from those assets. Insiders use all available cash to buy as long as price is less than 1. Outsiders have a lower valuation, so they bid as long as price is L or less. One assumption I use is that when both insiders and outsiders have bids at the same price, insiders have priority.

The supply quantity of distressed assets is given by all defaulted firms; thus it does not depend on prices. Given the form of the supply and demand functions, I can solve for p once I determine S and $\bar{c}^1$.

Lemma 2. *Prices depend on the information available at $t = 1$ (i.e., $\mathcal{F}_1$) and are given by*

$$p(\mathcal{F}_1) = \max\left(L, \min\left(1, \frac{\textit{Available Cash}}{\textit{Amount Distressed Assets}}\right)\right) \tag{2}$$

If there is a symmetric equilibrium, let $\bar{c}$ be the cash saved at time 0 by each insider. Then p depends on z and $\bar{c}$, and

$$Available\ Cash = N\left[\frac{\bar{c}+\mu+\sigma_y z}{\sigma_x}\right](\bar{c}+\mu+\sigma_y z) + \phi\left[\frac{\bar{c}+\mu+\sigma_y z}{\sigma_x}\right]\sigma_x \tag{2.1}$$

$$Amount\ Distressed\ Assets = 1 - N\left[\frac{\bar{c}+\mu+\sigma_y z}{\sigma_x}\right] \tag{2.2}$$

Lemma 2[3] gives the general form of prices. Moreover, when all firms hold the same amount of cash, prices depend only on the unique cash policy and the systematic shock to cashflow z. Given $\bar{c}$, for low enough z, prices are L, and for high enough z prices are 1. In between the two bounds, prices increase strictly in z.

Firm optimum

When the firm survives ($F + c > 0$) and $p < 1$, it buys $\frac{F+c}{p}$ units of assets and the total payoff at $t = 2$ is $1 + \frac{F+c}{p}$. In case $p = 1$, the firm may have some cash not invested in assets. I assume that it invests this in a riskless technology that has a $NPV = 0$, making the total payoff at $t = 2$ equal to $1 + \frac{F+c}{p}$.

When the firm fails ($F + c < 0$), it sells its assets at p and the total payoff at $t = 1$ is $F + c + p$.

The firm raises cash c at time 0 from risk-neutral investors. The setup is isomorphic with an alternative where the firm has a large amount of cash from previous periods and it decides how much to keep and how much to distribute to shareholders.

Given pricing functional $p(\mathcal{F}_1)$, the firm solves the following problem at $t = 0$:

$$\max_{c\geq 0} f(c,p) = E_F\left[1_{F+c>0}\left(1+\frac{F+c}{p}\right) + 1_{F+c<0}(F+c+p)\right] - \xi(c) - E[PayoutForCashRaised]$$

Given fair pricing at $t = 0$ for any cash raised at this point, $E[PayoutForCashRaised] = c$ and the problem simplifies to

$$\max_{c\geq 0} f(c,p) = E_F\left[1_{F+c>0}(F+c)\left(\frac{1}{p}-1\right) + 1_{F+c<0}(p-1)\right] + \mu + 1 - \xi(c)$$

Using the definition of F, noting that p does not depend on the idiosyncratic shock z_α and integrating over z_α, we get:

[3] There are certain issues discussed in the proof related to the fact that the law of large numbers does not exist for a continuum of agents

$$\max_{c\geq 0} f(c,p) = E_z\left[\left(N\left[\frac{c+\mu+\sigma_y z}{\sigma_x}\right](c+\mu+\sigma_y z)+\phi\left[\frac{c+\mu+\sigma_y z}{\sigma_x}\right]\sigma_x\right)\frac{1-p(\mathcal{F}_1)}{p(\mathcal{F}_1)}-\right.$$

$$\left.-\left(1-N\left[\frac{c+\mu+\sigma_y z}{\sigma_x}\right]\right)(1-p(\mathcal{F}_1))\right]+\mu+1-\xi(c) \quad (3)$$

$N[\cdot]$ and $\phi[\cdot]$ are the usual normal density functions. Note that the firm cares about other firms' cash only inasmuch as it affects prices.

Noting that the firm is a price-taker, I get the FOC by differentiating (3) with respect to c:

$$0 = f_c(c,p) = E_z\left[N\left[\frac{c+\mu+\sigma_y z}{\sigma_x}\right]\frac{1-p(\mathcal{F}_1)}{p(\mathcal{F}_1)}+\frac{1}{\sigma_x}\phi\left[\frac{c+\mu+\sigma_y z}{\sigma_x}\right](1-p(\mathcal{F}_1))\right]-\xi c \quad (4)$$

The FOC (4) is true for all types of equilibria, as long as some firms hold c in equilibrium.

The FOC show that the marginal benefits to cash depend on the probability that the firm is in distress, the amount of money it has if it is not, and on the price of assets. The form of the value function agrees with the intuition that the characteristics of other firms affect the firm through the price of assets. This fact would be more transparent in a more elaborate version of the model, where firms are heterogeneous ex-ante. In an additional effect, the value function depends directly on the distribution of the industry shock, but that is not to be confused with a direct connection with other firms' properties. This effect is due to firms having a similar production function.

2.3 Equilibrium Characterization

I characterize the equilibrium based on theoretical results derived in Appendix A. When theoretical results are not available, I use numerical solutions based on various reasonable sets of parameters. The numerical approach yields precise conclusions because the structure of (4) gives an upper bound on optimum cash policy c. First, I investigate the existence and uniqueness of symmetric equilibrium, the natural type of equilibrium in this setup. Second, I investigate the form, existence and uniqueness of asymmetric equilibria, and focus on the two-strategy one.

Given the fact that there are a continuum of identical firms, there is no distinction between pure-strategy asymmetric equilibrium and mixed-strategy symmetric equilibrium. For consistency, I will use only the first term. In a more general setup where firms are heterogeneous, the two types of equilibria may be different.

An important issue is the existence of multiple equilibria for the same economy. Based on my numerical investigations, the symmetric and two-strategy equilibria do not exist simultaneously and, moreover, when they exist they are unique among their class. Regarding other possible equilibria, my conjecture is that they do not exist in non-degenerate cases. For an n-strategy equilibrium to exist, the firm objective function must have n local optima. I did not find any combination of parameters (including off-equilibrium distributions in cash policies) that results in an objective function with more than two local optima. In fact, there are cases when the equilibrium is symmetric, yet the value function has two local optima. Given that value functions with two local optima are quite common even for equilibria that do not have two strategies, while value functions with more than two optima are not, it is difficult to entertain the possibility that asymmetric equilibria with more than two strategies are possible.

Using the expression (4) for FOC, the fact that $p(\mathcal{F}_1) \geq L$, and the properties of the normal distribution, I obtain that for any $c > c_{sup}$, where $c_{sup} = \frac{1}{\xi}\left(\frac{1-L}{L} + \frac{1}{2\pi\sqrt{\sigma_x^2+\sigma_y^2}}(1-L)\right)$, the *lhs* of (4) is negative. Hence, *under any type of equilibrium*, the set of allowable policies are in the interval $[0, c_{sup}]$

Symmetric equilibrium

To get optimum cash policy c^* given a symmetric equilibrium, I solve the FOC (4) for $c^* = c = \bar{c}$ and p given by (2.1) – (2.2). In the symmetric case p is a function of z and $\bar{c}$ only. The exact numerical algorithm is given in Appendix A.

Proposition 1. *(a) Any symmetric equilibrium c^* satisfies* (4) *for $c^* = c = \bar{c}$ and $p(z, \bar{c})$ given by* (2.1) – (2.2). *The necessary and sufficient condition for the solution c^* to* (4) *to be an equilibrium is to be a global maximum: $f(c, p(z, c^*)) < f(c^*, p(z, c^*))$ for any $c \geq 0$, $c \neq c^*$*

(b) When it exists, the symmetric equilibrium is unique among the class of symmetric equilibria.

(c) If $\sigma_x > 0$, there is systematic volatility $\bar{\sigma}_y$ such that a symmetric equilibrium exists if $\sigma_y \leq \bar{\sigma}_y$. Moreover, $\bar{\sigma}_y$ increases in L (the reverse of asset specificity)

Proposition 1.*c* states that a symmetric equilibrium exists if and only if the systematic uncertainty is low enough. Albeit in this case it may exists also asymmetric equilibria, the symmetric equilibrium is unique. In fact, we shall see in the next section that a certain type of asymmetric equilibria can be ruled out when symmetric equilibria exist. Further, the threshold systematic volatility separating the symmetric from asymmetric equilibria, is decreasing in asset specificity.

For the special case, presented in Appendix A, of no systematic uncertainty, the results concerning existence and uniqueness can be strengthened. When $\sigma_y = 0$, there always exists an equilibrium and that equilibrium is unique and symmetric. The uniqueness is not only among symmetric equilibria, but among all possible equilibria.

The symmetric equilibrium generates interesting, empirically testable, comparative statics of the optimal cash policy with respect to the key and novel model parameters, namely asset specificity and systematic cashflow volatility. I obtain the results numerically and check them over a sensible range of parameters—see Figure 1.

Proposition 2. *When symmetric equilibrium exists*

(a) $\frac{dc^*}{dL} < 0$ *The ratio of industry cash holdings to industry net assets is positively related to asset specificity*

(b) $\frac{d^2c^*}{dLd\sigma_y} < 0$ *The ratio of industry cash holdings to industry net assets is positively related to the product of asset specificity and industry cashflow volatility*

The link between asset specificity and optimal cash is intuitive and straightforward: An increase in asset specificity means a downward shift in some parts of the demand curve, decreasing prices in some states and increasing the incentives to hold cash.

Systematic cashflow volatility affects the incentives to carry cash differently depending on the direction of the systematic cashflow shock. In the case of a positive shock, firms are doing fairly well and demand for assets is high while supply is low, which makes carrying cash unattractive. Given a positive shock, the higher the systematic volatility, the lower the marginal benefits of cash. The converse argument can be made for a negative systematic shock: It increases the marginal benefits of cash, generating a positive relationship between the systematic volatility and optimal cash. *Ex ante*, at time 0, it is unclear what the dominating effect of an increase in systematic cashflow volatility on optimal cash is.

The unambiguous cross-effect of the two variables on optimal cash stems from the difference in how they interact, conditional on the direction of the systematic shock. With a negative shock, the valuation to outsiders has a high probability of affecting prices, since insiders' cash is likely not enough to buy all distressed assets at high prices. The higher the asset specificity, the lower the prices can go in case of a bad shock, and the effect of asset specificity and systematic volatility compound each other, generating a positive cross effect on optimal cash. In the case of a positive shock, the valuation by outsiders is unlikely to play any role in pricing, hence there would be no cross effect. Thus, any contribution of the two variables to the cross effect comes from the states when the industry is facing a negative shock.

Asymmetric equilibrium

The results from the previous section show that a symmetric equilibrium may not always exist. Next, I investigate the existence and properties of asymmetric equilibria. In an asymmetric equilibrium, firms separate into different groups and each group follows its own cash policy, yet firms are optimally indifferent about choosing to what group to belong. The equilibrium definition must be changed accordingly (see Appendix A) to account for firms' holding different amounts of cash, making prices dependent on the non-uniform distribution of cash policies across firms.

Asymmetric equilibrium implies that a firm's objective function should have n global maxima, where n is the number of groups of firms. Solving for such an equilibrium involves solving numerically a system of $2n-1$ equations similar to the one for the symmetric equilibrium case, a daunting task indeed. Given these challenges, I look at equilibria with only 2 potential strategies.

When firms separate into 2 groups with each group holding a different amount of cash, the equilibrium is defined by three quantities that must be computed: the amount of cash each group holds (c_1^* and c_2^*) and the percentage of firms that hold c_2^* in cash (η). The three equations required to derive the equilibrium are given by the condition that c_1^* and c_2^* are extremum points for the firm's objective function (FOC equation (4) holds for $c = c_1^*$ and for $c = c_2^*$) and the condition that the firm is indifferent to the choice between holding c_1^* or c_2^* (the objective function is the same at c_1^* and at c_2^*). Moreover, the pricing equation (2) changes as well to account for the two groups of firms. The detailed equations are given in Appendix A.

Proposition 3. *(a) Any two-strategy equilibrium requires $1-\eta$ firms holding c_1^* in cash and η firms holding c_2^* in cash, where $\eta \in [0,1]$. The quantities c_1^*, η and c_2^* solve the equations given in Appendix A. The solution is an equilibrium iff both c_1^* and c_2^* are global maxima of $f(\cdot, p(z, \eta, c_1^*, c_2^*))$*

(b) When it exists, the two-strategy equilibrium is unique among the class of two-strategy equilibria, which includes the symmetric class as a special case.

(c) If $\sigma_x > 0$, there is systematic volatility $\bar{\sigma}_y$ such that the two-strategy equilibrium degenerates into a symmetric equilibrium if $\sigma_y \leq \bar{\sigma}_y$. The threshold $\bar{\sigma}_y$ increases in L.

This proposition states that there is no overlap between symmetric equilibria and non-degenerate two-strategy equilibria. When they exist, two strategy-equilibria are unique. Proposition 3.*c*, is the same result as proposition 1.*c*: there is a systematic volatility level below which there exist only symmetric equilibria and above which there exist only two-strategy equilibria.

For the particular case where there is no idiosyncratic uncertainty (i.e., $\sigma_x = 0$), I show in Appendix A that (i) there is no symmetric equilibrium and (ii) any equilibrium requires a group of firms to hold 0 cash. Thus the solution to any two-strategy equilibrium is obtained via only two equations (for c_2^* and η).

In the case of two-strategy equilibria, the comparative statics of average optimal cash in the industry follow the same patterns as described in Proposition 2. Yet, in contrast with the symmetric equilibrium, in this case the distribution of cash across firms is not a single point and it has a meaningful second moment. Its comparative statics with respect to asset specificity and systematic cashflow volatility generate novel empirical implications.

Proposition 4. *Define the "intra-industry variability of cash" (S) to be the standard deviation of the distribution of cash across firms (e.g., for two-strategy equilibrium it is* $\sqrt{\eta(1-\eta)(c_2^* - c_1^*)^2}$*). When two-strategy equilibria exist:*

(a) $\frac{dS}{dL} < 0$ *The intra-industry variability of the ratio of cash holdings to net assets is positively related to asset specificity*

(b) $\frac{dS}{d\sigma_y} > 0$ *The intra-industry variability of the ratio of cash holdings to net assets is positively related to industry cashflow volatility*

By noting that the range, or intra-industry variability, of cash is positively related to the systematic volatility and asset specificity, this proposition gives the comparative statics of the second moment of optimum cash's distribution, an object that has not been studied before, theoretically or empirically—see Fig. 2. To understand the link between the range in cash and systematic volatility, I investigate the case where there is little or no idiosyncratic shock.

Given a similar cash policy, the more important the common component in cashflow is, the more likely that firms will survive or default together. In that case, abstracting for other costs of default not modeled here, a firm is better off holding no cash at all, saving the cost of cash. By holding no cash, the firm defaults in more states. But in those states everybody else survives, bailing out the firm. Moreover if it were to carry cash, the firm would never get to use it to buy other firms because there are no distressed firms when it survives. In equilibrium, firms follow mixed strategies and separate into different groups where some hold a large amount of cash and some hold less of it even though all firms are identical *ex ante*. Firms use their cash policy to undo the commonality in defaults and survival induced by the commonality in cashflows.

The reason why firms separate into different groups stems from the effect of commonality of defaults. However, the costs imposed on firms by commonality of defaults when they follow similar cash policies are diminished if outsiders have a higher valuation for the assets. In that case, prices remain high no matter what policies insiders follow. Therefore, firms have lower incentives to separate into various groups when valuation to outsiders L is high.

2.4 Empirical Predictions

I obtain a set of empirical predictions based on the results about the existence of various equilibria and on the comparative statics of the distribution of optimal cash across firms (Propositions 1 through 4). The predictions concern two key variables: asset specificity and systematic cashflow volatility. More specifically, I investigate the behavior of average cash and of the intra-industry variability, or range, of cash.

Prediction 1. *The ratio of industry cash holdings to industry net assets is (see Figure* 1*)*

(a) positively related to asset specificity

(b) positively related to the product of asset specificity and industry cashflow volatility

Prediction 2. *The intra-industry variability of the ratio of cash holdings to net assets is (see Figure* 2*)*

(a) positively related to asset specificity

(b) positively related to industry cashflow volatility

These comparative statics are obtained over both types of equilibria investigated. For example, industry cash holdings are given by the optimum cash in case of symmetric equilibria, and by the weighted average of the two optimum values of cash in case of two-strategy, asymmetric equilibria. Moreover, since only one equilibrium exist for a certain set of parameters, thus there is only one value of industry cash holdings for a given level of asset specificity and industry cashflow volatility.

In Appendix A I relax the assumption that surviving firms cannot access external financing at $t = 1$. I allow them to pledge α of the $t = 2$ cashflow generated by the newly acquired assets. The comparative statics of optimum cash with respect to the two key variables is shown in Figure 4. Note that Prediction 1 holds.

3 Data

Asset Specificity Measures

To test these hypotheses I must measure asset specificity, a difficult task.[4] The first measure is based on Maksimovic and Phillips (2001) findings that firms do not branch into industries where they cannot efficiently use the assets. Therefore, it is natural that industries where there are more single-segment firms show higher asset specificity. In detail, I assign to all segments from the Compustat Segments database a value of 1 if, for that year, the firm does not have other segments in different industries, and a value of 0 otherwise. I take the sales-weighted average over all the segments in that year and industry. I use sales as a weighting measure since it is the only size-related proxy available at the segment level. Further, I obtain the "Segments" proxy for asset specificity by averaging the measure for each industry over entire time period. This proxy contains information from only the last 15 years (the Compustat Segments data start in 1990), producing less relevant results if the level of asset specificity differed between the two halves of the sample.

Another natural proxy for asset specificity is the proportion of intangible assets in an industry. The reason is that out of all assets, intangibles are arguably the hardest to measure, value, and understand, especially by a non-insider. When a company claims to have a research breakthrough, few from outside that industry may understand whether that would give them a long-term market advantage or whether they will be shortly overtaken by new technologies.

Measuring intangibles is challenging. In particular the balance sheet measure misses important items such as capitalized R&D or branding. Following the accounting literature, which recognizes that up to 50% of intangibles may be capitalized R&D, I capitalize R&D by adding R&D expenses, depreciated linearly at 20% per year. Using capitalized R&D, I construct a measure of industry intangibles based on industry-level items obtained by summing over all firm-year observations scaled by CPI. Thus, the second proxy of asset specificity is

$$\text{CapitR\&D+Intangibles} = \frac{\text{Ind. Capitalized R\&D} + \text{Ind. Balance Sheet Intangibles}}{\text{Ind. Capitalized R\&D} + \text{Ind. Book Assets}}$$

Intangibles not captured by the balance sheet may still be reflected in the market value of the company. In fact, the accounting literature shows a strong link between various types of off-balance-sheet intangibles and M/B. The last proxy I use is the M/B computed at the industry level in a manner similar to the second proxy above.

The last two measures proxy for various other concepts. Before any tests of my theory, I

[4] See David and Han (2004) for a survey of asset specificity measures. Except R&D, all are survey-based.

must purge any effects each firm's M/B, R&D or intangibles may have on its cash policy, leaving only the effects from the measures' inter-industry variation. Except for the theory presented here, no one else explains why the M/B or R&D of other firms in the same industry should affect one's cash policy beyond how one's own M/B or R&D do. My theory predicts that, *after accounting for the effects of intangibles at firm level*, the amount of intangibles in an industry should be a determinant of cash.

Other Data Definitions

I use the Compustat and Compustat Segments data between 1962 and 2004, maintaining only non-ADR firms from non-regulated industries, non-financial, for-profit sectors—i.e., construction (NAICS code 23), manufacturing (code 3), trade and transportation (code 4) and information services (code 51). I filter the data for missing key variables, to insure enough observations per industry, and to exclude outliers and observations from firms in special situations (details are given in Appendix B).

List of control variables

Variable	Type	Definition
Ln(Age)	Trend	From start of Compustat records
M/B	Time-varying, endog.	(Book Assets-Book Equity+Market Cap)/Book Assets
Log Size	Time-varying, endog.	Ln((Book Assets-Cash&Equiv.)/CPI)
ST Debt/Assets	Time-varying, endog.	Book Debt Due in < 1 yr/Book Assets
LT Debt/Assets	Time-varying, endog.	Book Debt Due in 1+ yr/Book Assets
R&D Exp/Sales	Time-varying, endog.	R&D Expenses/Sales
Working Cap/Assets	Time-varying, endog.	(Curr. Liab-Curr. Assets-Cash&E)/(Assets-Cash&E)
Capex/Assets	Time-varying, endog.	Capital Exp/(Book Assets-Cash&Equiv)
Acquisitions/Assets	Time-varying, endog.	Acquisitions/(Book Assets-Cash&Equiv)
Divid. Dummy	Time-varying, endog.	1 if firm paid dividends, 0 othw.
LT Debt/Total Debt	Time-varying, endog.	Book Debt Due in 1+ yr/Total Book Debt
M&Eq/Assets	Time-varying, endog.	Machinery & Equipm./(Book Assets-Cash&Equiv)
Intangibles/Assets	Time-varying, endog.	Intangibles/(Book Assets-Cash&Equiv)
Cash Flow/Assets	Time-varying, predet.	(Earnings before EI+Deprec.)/(Book Assets-Cash&E)
Firm Cash Flow Vol	Time-constant, exog.	see text
Cash Cycle	Time-varying, endog.	see Kim, Mauer, and Sherman (1998)
Cash Cycle Vol	Time-constant, exog.	see text

Firms are separated into industries based on their 3- and 4-digit NAICS code. The NAICS classification is better suited to my theory since the criterion used to group firms is the similarity of their inputs, while SIC is based on similarity of outputs. I group firms from manufacturing, retail trade, and information at the 4-digit level, while I group construction, transportation, and wholesale trade at the 3-digit level, since a further division is not meaningful.

Cash is measured as "cash and marketable securities" scaled by net size, which is book value less cash. The list below details the definition of all other determinants of cash that are suggested by the prior literature and I include in the empirical tests.

The summary statistics, reported in Table 1, correspond to the rest of the literature, except that cash is higher and debt lower due to data over the last decade. Moreover, the correlation among the measures of asset specificity is positive but not very high.

The source of the data on mergers and acquisitions is SDC Platinum. I retain both the target's and acquirer's primary NAICS to classify the transaction as between firms from the same industry (sale to insiders) or from different industries (sale to outsiders). Further, I use the ratio of transaction value to book assets of the target as a measure for unit price. I Winsorize the unit price at 1%. The ratio is aggregated annually for each industry (equal-weighted) separately for the sales to insiders and sales to outsiders. In unreported results I do the annual aggregation weighted by the book value of the target, without making a significant difference in the results.

4 Strategic Interactions and Empirical Patterns in Firms' Financial Policies

In this section I uncover empirical evidence about the effects of strategic interaction on firms' financial policy. I start by constructing an empirical methodology that accounts for other, previously documented, determinants of cash. The methodology is carefully designed to wrestle with the endogeneity and persistence of many of these previously documented determinants.

I test whether the empirical predictions of the theory about industry-wide patterns in financial policies bear in the data, and whether there may be some other potential explanations for the results. Moreover, I look at evidence from the mergers and acquisitions market and see whether it is consistent with a link between asset specificity measures and industry cash holdings that is due to the interaction in the asset sales market.

4.1 Methodology

To construct the empirical tests I proceed in two stages. In the first stage I account for other determinants of cash found in the literature, and in the second stage I test my model's empirical predictions. The two-stage approach provides a clearer presentation of the tests, since in the first stage I focus on the controls, while in the second I account for any unexplained industry effects using the predictions of my theory about industry cash. Moreover, by using this approach I can control for any industry effects unexplained by my theory.

At the first stage, I use an empirical model where cash depends on its lag, a set of control variables, and a set of industry dummies $\{\alpha_J\}_J$ and time dummies $\{\alpha'_\tau\}_\tau$.

$$Cash_{i,t} = \gamma Cash_{i,t-1} + \beta X_{i,t} + \sum_J \alpha_J 1_{i \in J} + \sum_\tau \alpha'_\tau 1_{t=\tau} + u_i + \epsilon_{i,t} \tag{5}$$

where u_i is a firm-specific error and $\epsilon_{i,t}$ is idiosyncratic error. Some controls—$X^v_{i,t}$—are time-varying and endogenous (e.g., leverage and capital expenditures), while the rest—X^n_i—are constant over time. I assume that X^n_i are exogenous, otherwise I cannot consistently estimate their coefficients given that $X^v_{i,t}$ does not have any exogenous elements.

Within controls (see the 'Data' section for the complete list and definition), compared to the rest of the literature, I separate leverage into long- and short-term components, on the grounds that the short-term portion should be more important in setting the current cash policy of the firm when considering the consequences of not being able to repay it. I also add the ratio of "long-term debt" to "total debt" as a measure of the term structure of firm's debt. The time-constant volatility measures (of cashflow and cash cycle) are computed for firms that have at least 12 observations. The rest of the firms are assigned the industry median where this is computed with respect to all firms in that industry that have at least 12 observations.

To estimate (5), I employ a dynamic panel data methodology developed in Anderson and Hsiao (1982), Arellano and Bond (1991) and Arellano and Bover (1995). This accounts for the presence of firm-specific error, lag cash, and potentially endogenous and persistent controls, all of which render any standard empirical specification—such as OLS, fixed effects, etc.—inconsistent.

Since X contains Ln(Age) and "age" is in fact a trend variable, I de-trend the data first by regressing cash on Ln(Age). The de-trended measure is used to estimate the coefficients on time-varying variables in (5) by using the Arellano and Bond (1991) methodology. I cannot estimate the coefficients on time-invariant variables (e.g., $\{\alpha_J\}_J$, cashflow volatility) at this step because the procedure involves first-differencing (5) to get rid of firm error u_i. Estimation is done via GMM with instrumental variables, where the instruments are lags of $X^v_{i,t}$ and lags of cash. In actual estimation I use 2 or 3 lags as instruments.

Once I have consistent estimates of γ, β^v and $\{\alpha'_\tau\}_\tau$, I construct the residuals

$$CashRes_{i,t} \equiv Cash_{i,t} - \hat{\gamma} Cash_{i,t-1} - \hat{\beta}^v X^v_{i,t} + \sum_\tau \hat{\alpha}'_\tau 1_{t=\tau}$$

I use these residuals at step 3 to estimate consistently the coefficients β^n and $\{\alpha_J\}_J$ in a pooled OLS regression.

The estimation of (5) (i.e., Stage 1) is quite involved, requiring the three steps detailed above. The consistency of each step is established in Anderson and Hsiao (1982). As opposed to other empirical studies, here all steps are required since the key coefficients are the ones on the industry dummies, $\{\alpha_J\}_J$. They contain, for each industry, the part of cash holdings unexplained by any other determinant identified in the literature (i.e., X). Since my theory explains average industry cash holdings, its effects should be isolated in the industry dummies' coefficients.

To test the hypothesis about the determinants of industry cash, I estimate the following via weighted least squares (WLS)[5], where the weights are given by the estimated variances of $\hat{\alpha}_J$ from the previous stage:

$$\hat{\alpha}_J = \lambda_{CFVol} CashFlowVol_J + \lambda_{AS} AS_J + \lambda_{CFV*AS} AS_J CFVol_J + err$$

Hypothesis 1, based on Prediction 1, specifies that

[5]See Saxonhouse (1976) for why the use of WLS is appropriate in this setting

a. $\lambda_{AS} > 0$

b. $\lambda_{CFV*AS} > 0$

I measure the cashflow volatility as the time-series standard deviation of the ratio of the total industry cashflow to total industry book assets.

To test the hypothesis about spread in cash across firms, I construct a measure of spread from residuals $u_i + \epsilon_{i,t}$. These contain the variation in cash unexplained by any controls or set of dummies. For each year and each industry, I Winsorize at 5% the residuals obtained at the last step of Stage 1, and separate them into quintiles. Further, for each year and industry, I subtract the average residual in quintile 1 from the average in quintile 5. This measure is time-averaged for each industry, generating a set of observations $\{S_J\}_J$.

To test the hypothesis about the spread in cash, I estimate the following via OLS:

$$S_J = \lambda^S_{CFVol} CashFlowVol_J + \lambda^S_{AS} AS_J + err$$

Hypothesis 2, based on Prediction 2, specifies that

a. $\lambda^S_{CFV} > 0$

b. $\lambda^S_{AS} > 0$

Asset specificity and cashflow volatility may contain a few outliers that drive the results, given the small sample. Moreover, both variables are measured with error. To account for these drawbacks, in additional tests of the two hypotheses I replace the actual measures of asset specificity and industry cashflow volatility by semi-parametric, ordinal rank ones. For each measure, I assign to each industry a rank from 1 to 10, thus generating a derived measure that has less noise and less of an outliers issue.

4.2 Firm Level Determinants of Cash

This section discusses the auxiliary results about the determinants of cash *unrelated* to strategic interaction. The results merit attention since I contribute to the literature by addressing the endogeneity and persistence of these determinants and add a dynamic component to the framework. As Table 2 shows, the data support a dynamic model of cash, and the coefficient on lag of 0.4 is very similar to what Guney, Ozkan, and Ozkan (2005) find for other major countries. Consistent with the literature, older, bigger, and lower-M/B firms do hold less cash. Separating the debt into its long-term and short-term components looks appropriate since short-term debt has a higher effect on cash. Moreover, the sign on debt contradicts the hypothesis that firms with more debt hold more cash to be able to service it. Results may suggest that firms simultaneously allocate some of the extra cash to savings and some to debt payments.

Working capital, acquisitions, and capital expenditures work in the same way, as expected. Less-profitable firms hold less cash, showing that an important source of liquid assets is the current cashflow. Moreover, more uncertainty, expressed through higher volatility of both cashflow and cash conversion, forces firms to hold more cash. The length of the cash conversion cycle, the dividend dummy, and the ratio of long-term debt to total debt are not significant.

Intangibles have a negative impact on cash, showing that they may affect cash at the firm level through other channels than asset specificity. For example, a high value of goodwill (included in intangibles) is a sign that the firm made a string of cash-based acquisitions in the past, depleting its internal resources.

Further, I report a test of the second-order autocorrelations in $\epsilon_{i,t} - \epsilon_{i,t-1}$ since the Arellano-Bond procedure is consistent only when there is no autocorrelation in $\epsilon_{i,t}$. I cannot reject the null of no autocorrelation.

In gauging the effect on cash of the controls X and the lag, I investigate the correlation between stage 1 fitted values and actual cash (reported at the bottom of Table 2), where fitted values are computed using the coefficient estimates and (5), and excluding the industry dummies ($\hat{Y}_{no\ ind}$). The squared correlation[6] of 11% shows that, after accounting for endogeneity, the explanatory power of the usual determinants of cash found in the literature is not very high, even though I added lag cash to the standard empirical model.

To investigate the explanatory power of industry dummies, I compute the squared correlation of actual vs. fitted values, where fitted values now include the industry dummies as well ($\hat{Y}_{all}$). The squared correlation of 18.8% shows that the industry effects explain as much as 7.8% of the variation in cash, a number comparable with the explanatory power of all other variables found in the literature. Thus, industry has a first-order unexplained effect on cash.

4.3 Interaction-Generated Patterns in Average Industry Cash

The main tests of the hypothesis about average cash are reported in Table 3. Each explanatory variable is de-meaned and raw variables are further scaled to unit standard deviation. The dependent variable is scaled by 100; hence the coefficients show the impact of the explanatory variables on average cash in % of book assets.

[6]Since endogeneity generates non-zero correlation between errors and fitted values, R^2 must be redefined. I use the squared correlation between actual and fitted values as R^2 substitute, to investigate the explanatory power of the model.

There is strong evidence that the specificity of assets in an industry affects the propensity of firms to hold cash. All proxies for asset specificity, both raw and rank measures, point strongly in that direction, as well as the "principal component" and "average rank" measures. The "principal component" is the principal component of all three measures, scaled to unit variance. The coefficients on raw asset specificity measures show the marginal effect of a one-standard-deviation increase given that the cashflow volatility is at the mean. A one-standard-deviation increase in asset specificity leads to an increase in average cash holdings in that industry of 1.5% to 2.5% of total net assets. Further, the coefficients on rank measures are of a similar magnitude once we account for scaling. To understand their significance, we may compare it to the median cash holdings of 6.7%.

The second prediction, that cash is related positively to the product of cashflow volatility and asset specificity, is confirmed by two of the proxies (both raw and rank), while the coefficient on "Intangibles + Capitalized R&D" is insignificant. The average rank is significant at the 3% level and the principal component is significant only at 15% (two-tail). Investigating the economic significance, a one-standard-deviation increase in both cashflow volatility and asset specificity leads to an increase in average cash holdings in that industry of .6% to 1.5% of total net assets. This effect is due solely to the interaction between cashflow volatility and asset specificity, in addition to the marginal effects. The effect of the rank measure mirrors the effect of actual measures. Moreover, the Herfindahl index, when added to the model, is insignificant and does not change any of the results.

The R^2 in all models is high, around 40% except for the "Segments" proxy. The unexplained industry effects account for 7.8% of the variation in cash across firms and years, and the industry interaction effects are capable of explaining 35% of that, or 2.7% of the overall variation. This is significant given that all the firm variables and time-series dummies account for just 11%.

The fact that the industry variables have explanatory power after accounting for the firm effects show that there are some determinants of cash not captured by individual firm properties. The explanation suggested by my framework is the strategic interaction with their industry peers via asset reallocations. The alternative hypothesis of no strategic interaction should result in no explanatory power for the industry characteristics once the firm characteristics are accounted for. Further enhancing the case for the existence of strategic interaction effects, a determinant of cash that has no counterpart at the firm level (the product between asset specificity and industry cashflow volatility) has explanatory power as it has been predicted by the theory.

4.4 Interaction-Generated Patterns in Intra-Industry Variability of Cash

The main tests of the hypothesis about the spread in cash are reported in Table 4. All explanatory variables and the dependent variable are scaled as described in the previous section. Supporting the theory, both industry cashflow volatility and asset specificity are main determinants of the spread in cash holdings within an industry. The higher the industry cashflow volatility, the higher the difference between firms that hold a lot of cash and firms that hold less. The size of the coefficients show that a one-standard-deviation increase in volatility leads to an absolute increase in the spread of 3%. The mean spread is 23.5% and the standard deviation is 9.5%, hence the effect is economically important. The results for rank measures support the ones for the raw measures.

All raw and rank measures of asset specificity, including their principal component, indicate that asset specificity in an industry plays a major role in determining the gap between firms with a lot of liquidity and firms with less liquidity in that particular industry. A one-standard-deviation increase in a measure implies an absolute increase of around 5% in the difference between firms in the first cash-to-net assets quintile and firms in the fifth quintile.

The size of economic effects is also important from the firm's point of view. Given the median cash of 6.7%, forcing an increase of $3 - 5\%$ in the gap between firms is rather significant.

The R^2 measures are very high as well, between 30% and 60%. Given that the dependent variable is not the actual cash, the economic meaning of R^2 is harder to interpret. It measures the explained variation across industries in the variation in cash within an industry.

These results use as object of analysis the amount of heterogeneity in cash holdings within an industry. This object is native to a framework with strategic interactions, and does not exist in a framework lacking the interaction feature. The fact that the predicted results hold is a powerful confirmation that the interaction feature is important, and the key observation that the unit of analysis should shift to the industry level has merit.

4.5 Other Potential Explanations for Industry Patterns in Cash

A first concern is about the measure of cashflow volatility. My theory does not distinguish between industry-specific shocks and market-wide shocks. One may argue that only industry-specific shocks matter, since only the financing to insiders is affected by systematic shocks. In a set of tests reported in the left section of Table 5, I use a market model of cashflow to extract the volatility of the component orthogonal to the market cashflow. The results using this volatility are similar to the ones reported for the general case.

To control for potential time heterogeneity in the relationships among the main variables, I construct the measures of asset specificity and cashflow volatility for each period. Further, I estimate the last step of Stage 1 for each period to obtain for each a separate set of industry dummies. Using these variables, I estimate the tests at each period and aggregate the coefficients over time. Due to time-dependence in the coefficients, I aggregate them using a model with first-order autocorrelated errors, where the dependent variable is the time-series of coefficients and the only regressor is an intercept. The middle section of Table 5 reports the results. The magnitude and significance of the coefficients confirms previous tests.

Based on the way the Segments proxy is constructed, the results for average cash using this proxy may be due to the fact that conglomerates hold less cash for reasons unrelated to asset specificity. While it can be shown algebraically that a bias does exist, all results hold almost unchanged when I estimate the industry dummies using a sample without conglomerates (see the right section of Table 5). The results are not affected by the bias, since there is a counter-bias because the theory is less significant for conglomerates than for other firms.

In further unreported checks, I use only R&D as a proxy for intangibles, without material changes in results. Additionally, I drop all observations with zero or missing R&D. Even though results weaken, partly due to using fewer industries, they still hold.

In this section I ruled out some potential alternative explanations, both econometric and economic, for the main results.

4.6 Industry-Wide Patterns in Net Debt

While the theory was developed in terms of cash, the main conclusions should hold for net debt as well. There is some degree of substitution between cash and debt capacity, even though it is not a perfect one. A firm that has to allocate an extra dollar may save part of it and use the rest to pay off debt. The firm saves in order to have liquidity in states when "debt capacity" is unavailable, while it simultaneously pays off debt since saving debt capacity is less costly than saving cash. In that light, I repeat the main tests of the two hypotheses using net debt. The methodology requires some minor changes: I drop all leverage variables as controls and add tangibility. The first-stage results are given in Table 2.

Table 6 shows the main results for net debt. They follow the same patterns as in the cash case. The amended hypothesis about average net debt predicts that the coefficients on asset specificity and the interaction term are both negative, with results supporting that prediction, except for the intangibles measures interacted with the volatility term. Interestingly, the size of the coefficients is almost double that for cash, showing that some of the effects come from pure debt.

The hypothesis about the spread in debt predicts a positive sign on both asset specificity and cashflow volatility. Results confirm this hypothesis as well. The coefficients are of similar size to the case of cash. Yet, one should not conclude that these results are due solely to cash because here the dependent variable is something similar to the second moment, so the effects of the explanatory variables on net debt spread are not the same as the sum of the effects on debt and negative cash spreads.

Overall, the results are consistent with the view that firms consider cash and debt capacity as partial substitutes and they pursue similar strategies for both. The strategic interaction affects not only the management of firms' cash holdings, but also the management of firms' debt capacity, which are the two main components of the financial structure.

4.7 Asset Sales, Average Industry Cash, and Asset Specificity

The theoretical explanation for the documented empirical patterns in cash holdings is the strategic interaction among firms through asset sales. In this section I will investigate some of the empirical predictions regarding asset sales and their connection with optimal cash holdings and the key exogenous variables in the model (i.e., asset specificity and industry cashflow volatility).

In industries with higher asset specificity, a negative shock to industry cashflow should lead to, on average, lower asset prices. This is a straight-forward implication of the interaction mechanism. In order to test this hypothesis I construct, for each industry-year, the average price-to-book ratio for sales to firms from the same industry as the target (sales to insiders) and the average price-to-book ratio (p/b) for sales to firms from a different industry than the target (sales to outsiders). Further, I compute the time-average of each of these two measures over the years where the industry was in an upturn, and the time-average over the years where the industry was in a downturn. An industry is considered to be in a downturn if the inflation-adjusted industry cashflow-to-assets is negative.

The price-to-book for sales to insiders during upturns should be (close to) the full value of the assets, while during downturn it should be lower. The hypothesis about asset specificity and prices implies that the difference between industry upturns and downturns in the insider sales price-to-book should increase in asset specificity. Table 7 shows that indeed there is a positive relation between asset specificity proxies and the difference in price-to-book for insiders, albeit the relation is significant for two out of three measures. A one-standard-deviation increase in asset specificity implies an increase in the change in takeover premium by 100%, which is significant given the median change in price-to-book of 114%.

Since the outsiders are less constrained and have lower valuation for the assets, the price-to-book they pay should not change too much with the change in industry conditions, and this change should be less related to asset specificity. In unreported results, the median decrease in price-to-book for sales to outsiders is only 85%, as opposed to 114% for sales to insiders. Further, as Table 7 shows, the decrease in the price-to-book is less related to asset specificity. The relation is virtually none for two proxies, and it is positive but insignificant for the third proxy.

The change in the price-to-book for insiders should covary with the optimum average cash holdings, since both are endogenous quantities and therefore a function of the same exogenous variables. Indeed, in industries with higher asset specificity we should observe both higher cash holdings and higher decrease in the price-to-book to insiders. Table 8 shows that the implied positive relation between cash and the decrease in the price-to-book holds in the data. An additional 100% decrease in the price-to-book implies a 0.5% higher industry cash-to-assets ratio. Further, once we add the exogenous variables to the model, there should be no connection between the decrease in price-to-book and average cash holdings. The results reported in Table 8 show that this is the case for two of the three measures of asset specificity.

It is expected to have a decrease in significance in Table 8 of the exogenous variables versus the standard model because I added an explanatory variable that should be endogenous and it absorbs some of the effects from the real exogenous variables. Contributing to the reduced significance is also the smaller sample size, only 50 industries that had enough asset sales to insiders with target book value data to be able to compute the change in the price-to-book.

The results from this section are consistent with the theory that asset specificity affects the properties of prices of productive assets, which in turn affect the benefits of carrying cash. Moreover, the connection between the prices of productive assets and cash is solely due to the exogenous variables posited by my framework.

5 Conclusion

This paper demonstrates how interaction among firms affects decision making regarding optimal financial policies. It argues that, due to strategic interaction, studies of financial policies should focus not only on individual firms but also on the industry as a whole. Empirical results strongly confirm the theoretical predictions about patterns in optimal cash policies, revealing asset specificity and industry cashflow volatility to be important determinants of both the average cash in an industry and the within-industry variability in cash. Further, the corresponding patterns in net debt polices are even more pronounced. Lastly, evidence about the effects of firm interaction on the market for productive assets agree with the framework described here.

Strategic interaction adds significantly to our understanding of the variation of cash policies. It explains an additional one-third of the variation in cash, above what is explained by interaction-unrelated effects. This is noteworthy given that determinants that result from interaction do not vary across time or within an industry.

The equilibrium has implications not only for the average of cash carried by firms in an industry, but also for the variability of cash within an industry. This quantity, a parameter of the distribution of cash within an industry, is examined in this article for the first time. Under the typical single-firm framework, the level of cash should be explained by firm characteristics, and this quantity would be either zero or noise. However, I show that when identical firms would survive or default together due to similar cashflows, they attempt to prevent this by following asymmetric financial strategies. This behavior generates heterogeneity in cash policies within an industry, increasing both in the industry component of cashflow and in the asset specificity component. These two variables explain almost half of the variation across industries in the difference between the first and fifth quintiles of cash within an industry.

To control for interaction-unrelated, firm-level determinants of cash found in the literature, I use a methodology different from that found in most previous studies—one which is better suited to deal with the endogeneity of some determinants, the persistence in both cash and its determinants, and the error component structure.

This paper offers a multi-agent model of financing and investment in the presence of external financing constraints. The endogeneity of liquidation prices due to interaction among firms should have consequences not only for cash policies but also for firm value, probability of default, and firm value in case of default. It may possibly lead to industry patterns in these variables. Exactly how equilibrium affects them remains a topic for future research.

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Appendix A - Theory

Proof Lemma 1

Let p be the unit price at time 1 of distressed assets. The unconstrained \$ demand function for a buyer given the cash-flow CF_2 he receives at $t = 2$ from assets bought:

$$d_{CF_2}(p) = \begin{cases} 0 & \text{if } p > CF_2 \\ [0,\, \infty) & \text{if } p = CF_2 \\ \infty & \text{if } p < CF_2 \end{cases}$$

Given that a surviving insider α receives 1 at $t = 2$ from each unit of the asset, his constrained quantity demand function given his cash c^1 at $t = 1$ is

$$\bar{d}_1(p) = \min\{d_1(p), c^1_\alpha / p\}$$

Since outsiders are unconstrained, their demand function is $d_L(p)$, making the aggregate demand to be $\int_{SurvInsider} \bar{d}_1(p) + \int_{Outsider} d_L(p)$.

Let $\bar{c}^1 = \int_\alpha 1_{c^1_\alpha \geq 0} c^1_\alpha$ the total cash available to insiders. The aggregate demand function is:

$$D(p) = \begin{cases} 0 & \text{if } p > 1 \\ [0,\, \bar{c}^1) & \text{if } p = 1 \\ \bar{c}^1/p & \text{if } L < p < 1 \\ [\bar{c}^1/L,\, \infty) & \text{if } p = L \\ \infty & \text{if } p < L \end{cases}$$

The amount of assets available for sale is the total number of distressed firms and does not depend on price.

Proof Lemma 2

In order to compute the total amount of cash available to surviving firms and the total number of distressed firms, I must integrate away the idiosyncratic randomness. However, the law of large numbers does not apply to uncountable sets such as a continuum of agents. There have been several solutions proposed in the literature that would technically modify the setup and deliver the LLN result. For a discussion on the issue and a solution see Alos-Ferrer (2002).

For each insider α, the cash available at $t = 1$ is $c^1_\alpha = c + \mu + \sigma_y z + \sigma_x z_\alpha$. Taking z as given and using the independence of the realizations of z_α across firms, the available cash to surviving firms is

$$\bar{c}^1 = E_\alpha \left[1_{z_\alpha > -\frac{c+\mu+\sigma_y z}{\sigma_x}} \left(c + \mu + \sigma_y z + \sigma_x z_\alpha \right) | z \right]$$

Using the properties of the normal distribution I get:

$$\bar{c}^1 = N \left[\frac{c + \mu + \sigma_y z}{\sigma_x} \right] (c + \mu + \sigma_y z) + \phi \left[\frac{c + \mu + \sigma_y z}{\sigma_x} \right] \sigma_x$$

The amount of assets available for sale:

$$S = 1 - E \left[1_{z_\alpha > -\frac{c+\mu+\sigma_y z}{\sigma_x}} | z \right] = 1 - N \left[\frac{c + \mu + \sigma_y z}{\sigma_x} \right]$$

Using the market equilibrium condition that $D(p) = S$ and the form of $D(p)$ from Lemma 1, the price of assets is:

$$p(z, c) = \max \left(L, \min \left(1, \frac{\bar{c}^1}{S_q} \right) \right)$$

The price does not depend on realizations of z_α, but only on the systematic cashflow shock z and the model parameters.

Available cash strictly increases in c and z, and the amount of distressed assets strictly decreases in c and z. This implies that exists $\bar{z}$ and $\underline{z}$ such that for any $z < \underline{z}$ the price is L, for any $z > \bar{z}$ the price is 1 and for any $\underline{z} < z < \bar{z}$ the price is $\frac{\bar{c}^1}{S_q}$ which strictly increases in c and z.

The equilibrium in the case of no systematic uncertainty

I consider a particular case where there is no systematic shock to cashflow (i.e. $\sigma_y = 0$). Since there is no systematic uncertainty, prices depend only on $\bar{c}$ - they are known at time 0 -, which can be seen by setting $\sigma_y = 0$ in (2). By solving the FOC (4) for $c^* = c = \bar{c}$ and p given by (2), I get the optimum cash policy c^*.

The form of both prices and the firm's FOC can be obtained by substituting $\sigma_y = 0$ in (2) and respectively (4). Thus the equilibrium is the unique positive solution c^* to

$$0 = f_c(c^*, p(c^*)) = \left(\frac{1}{p(c^*)} - 1 \right) N \left[\frac{c^* + \mu}{\sigma} \right] + (1 - p(c^*)) \frac{1}{\sigma} \phi \left[\frac{c^* + \mu}{\sigma} \right] - \xi c^*$$

The price of assets depends only on c and is given by

$$p(c) = \max\left(L, \min\left(1, \frac{N\left[\frac{c+\mu}{\sigma}\right](c+\mu) + \phi\left[\frac{c+\mu}{\sigma}\right]\sigma}{1 - N\left[\frac{c+\mu}{\sigma}\right]}\right)\right)$$

The form of the pricing function shows that prices depend only on the information available at $t = 0$, which is to be expected given that there is no systematic uncertainty.

Further, I will show that there is a unique positive equilibrium and it is symmetric.

Consider the second derivatives of the objective function:

$$f_{c,p}(c, p(\bar{c})) = -\frac{1}{p(\bar{c})^2} N\left[\frac{c+\mu}{\sigma}\right] - \frac{1}{\sigma}\phi\left[\frac{c+\mu}{\sigma}\right] < 0$$

$$f_{c,c}(c, \bar{c}) = \frac{1 - p(\bar{c})}{\sigma^2}\left(\frac{\sigma}{p(\bar{c})} - \frac{c+\mu}{\sigma}\right)\phi\left[\frac{c+\mu}{\sigma}\right] - v$$

If $\frac{\sigma}{p(\bar{c})} < \frac{c+\mu}{\sigma}$ then $f_{c,c}(c, p(\bar{c})) < 0$. Otherwise, $f_{c,c,c}(c, p(\bar{c})) < 0$ if $\mu > 0$, which I do assume. Hence $f_c(c, p(\bar{c}))$ is concave for $c \in [0, \frac{\sigma^2}{p(\bar{c})} - \mu]$ and decreasing afterwards. This property combined with the facts that $f_c(0, p(\bar{c})) > 0$ and $\lim_{c\to\infty} f_c(c, p(\bar{c})) = -\infty$, results that the objective function has, for any given $\bar{c}$, a unique maximum on the $[0, \infty)$ interval. The unique maximum precludes the existence of any multiple strategy equilibria, since that requires the existence of multiple maxima. Thus we proved that any equilibrium must be symmetric.

Given that $f_c(0, p(c)) > 0$ and $\lim_{c\to\infty} f_c(c, p(c)) = -\infty$, there must be a c^* such that $f_c(c^*, p(c^*)) = 0$. Moreover, given the properties of f_c, SOC are satisfied as well at c^*. Thus a symmetric equilibrium always exists.

Let c^* be a symmetric equilibrium. Next, I will prove that it does not exist any other symmetric equilibrium. Assume there is another symmetric equilibrium c^{**} and WLOG $c^{**} > c^*$. Given the properties of $p(c)$, $p(c^{**}) \geq p(c^*)$. Given that $f_{c,p}(c, p) < 0$, then for any c we have $f_c(c, p(c^{**})) < f_c(c, p(c^*))$. Thus

$$f(c^{**}, p(c^{**})) - f(c^*, p(c^{**})) = \int_{c^*}^{c^{**}} f_c(x, p(c^{**}))dx \leq \int_{c^*}^{c^{**}} f_c(x, p(c^*))dx =$$

$$= f(c^{**}, p(c^*)) - f(c^*, p(c^*)) < 0$$

The first inequality comes from the previous paragraph results. The last inequality results from the optimality of c^*. Therefore $f(c^{**}, p(c^{**})) < f(c^*, p(c^{**}))$, contradicting the optimality of c^{**}.

Proof Proposition 1

Point *(a)* stems directly from the definition of the equilibrium.

The proof for *(b)* is similar to the proof for the case of no systematic uncertainty. First we must establish that if both c^* and c^{**} are symmetric equilibria and WLOG $c^{**} > c^*$ then for any $c > c^*$ we have $f_c(c, p(z, c^{**})) \leq f_c(c, p(z, c^*))$.

For any given z, we have that $p(z, c)$ increase in c. Further, define

$$g(z, c, \bar{c}) \equiv N\left[\frac{c + \mu + \sigma_y z}{\sigma_x}\right] \frac{1 - p(z, \bar{c})}{p(z, \bar{c})} + \frac{1}{\sigma_x}\phi\left[\frac{c + \mu + \sigma_y z}{\sigma_x}\right](1 - p(z, \bar{c}))$$

By definition, $f_c(c, p(z, \bar{c})) = E_z[g(z, c, \bar{c})] - \xi c$. Given that $\partial g(z, c, \bar{c})/\partial p < 0$, then $g_{\bar{c}}(z, c, \bar{c}) \leq 0$ and $f_{c,p}(c, p(z, \bar{c})) < 0$. Thus for any $c > c^*$ we have $f_c(c, p(c^{**})) \leq f_c(c, p(c^*))$.

Further, the proof proceeds along the lines of proof for the special case of no systematic uncertainty.

I do not prove point *(c)* theoretically. However, it is true over all parameters' ranges considered for the numerical solution. An intuitive proof relies on the fact that it exists only a symmetric equilibrium when $\sigma_y = 0$, and it exists a two strategy equilibrium but not a symmetric one when $\sigma_x = 0$. Given that the model is continuous, there must be $\bar{\sigma}_y$ for a given σ_x such that a symmetric equilibrium exists iff $\sigma_y \leq \bar{\sigma}_y$.

Algorithm used for the numerical solution to symmetric equilibrium for the general case

Let $\tilde{c} \equiv \frac{c+\mu}{\sigma_x}$ and $a \equiv \frac{\sigma_y}{\sigma_x}$

Combining equations (4) and (2) with the existence of $\bar{z}$ and $\underline{z}$ such that $p = 1$ iff $z \geq \bar{z}$, $p = L$ iff $z \leq \underline{z}$ and $1 > p > L$ otherwise, any symmetric equilibrium c is a solution to

$$\begin{aligned}0 = &- \xi c + \int_{-\infty}^{\underline{z}} \left(\frac{1-L}{L} N\left[\tilde{c} + az\right] + (1-L)\frac{1}{\sigma_x}\phi\left[\tilde{c} + az\right]\right) dN[z] + \\ &+ \frac{1}{\sigma_x}\int_{\underline{z}}^{\bar{z}} \left(\left(\frac{1 - N\left[\tilde{c} + az\right]}{\left(N\left[\tilde{c} + az\right](\tilde{c} + az) + \phi\left[\tilde{c} + az\right]\right)} - \sigma_x\right) N\left[\tilde{c} + az\right] + \right. \\ &\left. \left(1 - \frac{\left(N\left[\tilde{c} + az\right](\tilde{c} + az) + \phi\left[\tilde{c} + az\right]\right)\sigma_x}{1 - N\left[\tilde{c} + az\right]}\right)\phi\left[\tilde{c} + az\right]\right) dN[z]\end{aligned}$$

Where $\underline{z}$ solves $\left(N\left[\tilde{c} + az\right](\tilde{c} + az) + \phi\left[\tilde{c} + az\right]\right)\sigma_x = L(1 - N\left[\tilde{c} + az\right])$

and $\bar{z}$ solves $\left(N\left[\tilde{c} + az\right](\tilde{c} + az) + \phi\left[\tilde{c} + az\right]\right)\sigma_x = 1 - N\left[\tilde{c} + az\right]$

One concern for a numerical solution is how to approximate the indefinite integral. Note that the quantity under the integral converges to 0 as z goes to $-\infty$. Moreover, the integral is taken with respect to $dN[z]$. Hence, for a low enough z_l, the integral from $-\infty$ to z_l is less than $N[z_l]$ which can be considered 0 for $z_l < -20$. Therefore the indefinite integral can be transformed into a definite integral, where the lower limit is $\min(-20, \underline{z})$.

Moreover, note that both $\underline{z}$ and $\bar{z}$ decrease linearly with c. For example let u solve $(N[u]u + \phi[u])\sigma_x = 1 - N[u]$. Then $\tilde{c} + a\bar{z} = u$. Since the two integrals become virtually 0 for $\bar{z} < -20$, then any solution satisfies $\tilde{c} < u + 20a$. Therefore I can limit the search for a solution to the equation above to $c \in (0, u - \mu + 20\sigma_y)$.

Further, I must verify whether the solution found an overall maximum of the objective function $f(c, c^*)$. First, I check whether the solution is a local maximum: $f_c(c^* - \epsilon, c^*) > 0$ and $f_c(c^* + \epsilon, c^*) < 0$. To check whether it is a global maximum, I note that any other possible maximum must occur at a level that is not too high, otherwise the effect of ξc component of f_c becomes overwhelming. Over this range, I investigate whether $f_c(c, c^*)$ has other zeroes and whether the objective function is higher at these extrema.

In conclusion, any numerical solution to the equation above can be numerically computed by searching, over a bounded domain, for the zero of a function.

Equilibrium definition given a general distribution of cash holdings across firms:

Equilibrium is a set $\{\mathcal{D}(c), p(\mathcal{F}_1)\}$, where $\mathcal{D}(c)$ is the distribution with support $C = \{c_i\}_i$ and set of probabilities $\Phi = \{\eta_i\}_i$ of time 0 cash policy across all firms and $p(\mathcal{F}_1)$ is time 1 distressed assets pricing functional. Equilibrium satisfies:

- insider firm attains its maximum value at time 0 if it holds in cash any $c \in C$, given that the cash of all other firms in the industry is distributed $\mathcal{D}(c)$ and prices at time 1 are given by p
- p is such that supply equal demand given the realization of time 1 cashflows and that the distribution of cash savings in the industry is given by $\mathcal{D}(c)$

By generalizing the proofs from Lemmas 1 and 2, it can be shown that

$$\bar{c}^1 = \sum_i \eta_i \left(N\left[\frac{c_i + \mu + \sigma_y z}{\sigma_x}\right](c_i + \mu + \sigma_y z) + \phi\left[\frac{c_i + \mu + \sigma_y z}{\sigma_x}\right]\sigma_x \right)$$

$$S = 1 - \sum_i \eta_i N\left[\frac{c_i + \mu + \sigma_y z}{\sigma_x}\right]$$

The updated definition of the pricing functional can be derived using the formula for prices from Lemma 2, which is still valid:

$$p(z, \mathcal{D}(c)) = \max\left(L, \min\left(1, \frac{\bar{c}^1}{S}\right)\right)$$

The special case of a two strategy equilibrium given that $\sigma_x = 0$ means that $\Phi = \{1-\eta, \eta\}$ and $C = \{0, c_2\}$. While the equilibrium definition is a specialization of the one above, prices are not. See the discussion under Lemma 3.

The general case of a two strategy equilibrium and $\sigma_x > 0$, specializes the general definition of equilibrium and prices to $\Phi = \{1-\eta, \eta\}$ and $C = \{c_1, c_2\}$.

Proof Proposition 3

The proof for a comes from the definition of the equilibrium. Further, the equations are an extended version of the solution algorithm given in the proof of Lemma 3.

An intuitive proof for b has the following steps:

(i) given c_1^* and η, the solution c_2^* to $f_c(c_2^*, p(\eta, c_1, c_2^*)) = 0$ when it exists, is unique;

(ii) given η, the solution c_1^* to $f_c(c_1^*, p(\eta, c_1^*, c_2^*(\eta, c_1^*)) = 0$ when it exists, is unique, where $c_2^*(\eta, c_1^*)$ is given by the condition from (i);

(iii) the solution η to $f(c_1^*(\eta), p(\eta, c_1^*(\eta), c_2^*(\eta, c_1^*(\eta)))) = f(c_2^*(\eta, c_1^*(\eta)), p(\eta, c_1^*(\eta), c_2^*(\eta, c_1^*(\eta))))$ when it exists, is unique, where $c_1^*(\eta)$ is given by (ii) and $c_2^*(\eta, c_1^*(\eta))$ is given by (i).

The theoretical proof for the first step follows the same lines as for the uniqueness of the symmetric equilibrium.

The intuitive proof for the second step: we want to show that, fixing η, an increase in c_1 decreases the marginal incentives to hold cash for the low cash firms given that high cash firms hold the optimum amount $c_2^*(\eta, c_1)$. Therefore the FOC for low cash firms has a unique solution as long as η is fixed and c_2^* is optimal for that η and c_1. To achieve that we must investigate the effect of a change in c_1 on $f_c(c_1, p(\eta, c_1, c_2^*(\eta, c_1)))$. First, an increase in c_1 leads to a decrease in $c_2^*(\eta, c_1)$. Further, an increase in c_1 affects p indirectly in a negative way (through the decrease in c_2^*) and directly in a positive way. Intuitively, the direct effect may be stronger since the change in $c_2^*(\eta, c_1)$ should only partially mitigate the effect of a higher c_1 on prices when deriving the equilibrium c_2^*. Moreover, the direct effect of c_1 on f_c is negative when c_1 is close to the value that satisfies FOC for low cash firms. Given that the negative effect of p on f_c is bigger as c_1 has a bigger increase from optimum, the overall effect of an increase in c_1 on $f_c(c_1, p(\eta, c_1, c_2^*(\eta, c_1)))$ is negative and, if it exists, the c_1^* that satisfies $f_c(c_1^*, p(\eta, c_1^*, c_2^*(\eta, c_1^*))) = 0$ is unique.

The last step of the proof notes that if η^* exists, then for any $\eta > \eta^*$ given that high cash firms hold $c_2^*(\eta, c_1^*(\eta))$ and low cash firms hold $c_1^*(\eta)$, the high cash firms should be worse off than low cash firms since there are more high cash firms at the higher η. The high cash firms may have been better off only if there was some sort of a "network effect", where if more firms switch to another group, the better off that group is. This model has no such effects, and more firms switching to a group make that group worse off compared to others. For example, more firms holding a lot of cash means that low cash firms will be bailed out at full price in more states and there are less buying opportunities for high cash firms.

For the proof of c, note that the uniqueness proof above doesn't rely on $\eta > 0$ and a symmetric equilibrium can be viewed as a special case of the two strategy equilibrium. Thus there cannot be a symmetric equilibrium and a two strategy equilibrium for $0 < \eta < 1$.

For the range of parameters I consider, the results of Theorem 3.b and 3.c hold true. To solve for the equilibrium quantities, I follow the details of the proof for Theorem 3.b.

The equilibrium in the case of no idiosyncratic uncertainty

Lemma 3. *For the case where there is no idiosyncratic uncertainty (i.e. $\sigma_x = 0$):*

(a) There is no symmetric equilibrium

(b) Any equilibrium must have $1 - \eta$ firms holding zero cash, where $\eta \in (0, 1)$

(c) Any two strategy equilibrium has η firms holding $c_2^* > 0$ in cash and $1 - \eta$ firms holding no cash, where η and c_2^* solve the equations given in Appendix A. The solution is an equilibrium iff both 0 and c_2^* are global maxima of $f(\cdot, p(z, \eta, c_2^*))$.

I will proceed as follows: assume the pricing function as given. Show that, based on the firm objective function, the symmetric equilibrium is not feasible. Then look for a two strategy equilibrium.

Firm Problem:

For a firm $\alpha \in [0, 1]$, the price p depends on z and the distribution of cash in the market. Both are not affected by firm α cash holdings. Price takes values between L and 1. Assuming that the price function is monotonic in z I will show in this section that the equilibrium distribution of cash holdings is: a measure $1 > 1 - \eta > 0$ of firms hold 0 in cash, and the rest hold non-zero amounts of cash.

Based on these assumptions there is a level $\bar{z}$ such that for any $z \geq \bar{z}$ the price is 1 and for any $z < \bar{z}$ the price is less than 1. Note that $\sigma_y \bar{z} + \mu \leq 0$ since for any $\sigma_y z + \mu \geq 0$ nobody defaults ($c \geq 0$ by definition) and price must be 1.

The assumption that the price increases in z will be proven in the analysis of the market equilibrium.

The objective function:

$$\max_{c \geq 0} f(c) = 1 + E\left[1_{z > -\frac{c+\mu}{\sigma_y}} 1_{z<\bar{z}} (c + \mu + \sigma_y z) \frac{1-p(z)}{p(z)} - (1 - 1_{z > -\frac{c+\mu}{\sigma_y}}) 1_{z<\bar{z}} (1 - p(z))\right] - \xi(c) =$$

In case $\frac{c+\mu}{\sigma_y} \leq -\bar{z}$ the first term from the expectation vanishes and the objective function is:

$$f1(c) = 1 - E\left[1_{z<\bar{z}}(1 - p(z))\right] - \xi(c)$$

The derivative of $f1$ is strictly negative. Since there are only costs to cash and no benefits, the optimum cash when $\frac{c+\mu}{\sigma_y} \leq -\bar{z}$ is 0.

In case $\frac{c+\mu}{\sigma_y} > -\bar{z}$ the objective function is:

$$f2(c) = 1 + E_z\left[1_{\bar{z} > z > -\frac{c+\mu}{\sigma_y}} (c + \mu + \sigma_y z) \frac{1-p(z)}{p(z)} - (1 - 1_{z > -\frac{c+\mu}{\sigma_y}})(1 - p(z))\right] - \xi(c)$$

Since the quantity under the expectation is always less than $c\frac{1-L}{L} + const$ and $\xi(c)$ is quadratic, there is a c_{sup} such that $f2(c) < f1(0)$ for any $c > c_{sup}$. Therefore no firm will hold $c > c_{sup}$ in equilibrium since the strategy is dominated by $c = 0$. Moreover, for any $z\sigma_y + \mu < -c_{sup}$ everybody defaults and $p = L$. This implies that it exists $\underline{z}$ such that $p(z) = L$ for any $z < \underline{z}$.

Using Leibnitz rule I get the derivative of the objective function:

$$f2'(c) = E_z\left[1_{\bar{z} > z > -\frac{c+\mu}{\sigma_y}} \frac{1-p(z)}{p(z)}\right] + \frac{1}{\sigma_y}\left(1 - p\left(-\frac{c+\mu}{\sigma_y}\right)\right)\phi\left[\frac{c+\mu}{\sigma_y}\right] - \xi c$$

There is no guarantee that $f2'(c) = 0$ has a unique solution. Yet it has at least a solution given that $f2'(0) > 0$ and $f2'(\infty) = -\infty$.

Proof of Lemma $3.a$**:** Assume the contrary: that a symmetric equilibrium exists. Then all firms hold $\bar{c}$ in cash. This implies that $\bar{z} = -\frac{\bar{c}+\mu}{\sigma_y}$ and the objective function $f(c) = f1(c)$ for any $c \leq \bar{c}$ and $f(c) = f2(c)$ for any $c \geq \bar{c}$. Given the equilibrium, the maximum of the objective function must be at $\bar{c}$. But for any $c < \bar{c}$ I have that $f(c) = f1(c) > f1(\bar{c}) = f(\bar{c})$. Contradiction. $c = 0$ is not an equilibrium either since $f2'(0) > 0$ so it exists $c > 0$ such that $f(c) = f2(c) > f2(0) = f(0)$. There is no symmetric equilibrium.

Proof of Lemma 3.b**:** Assume the contrary. If no firm holds 0 cash, then the firm finds optimal to switch to 0 cash. Any level c_i that is held in equilibrium by a group of firms must be a global optimum, hence $f(c_i) > f(0)$. Moreover, $0 > -\min(c_i) \geq \mu + \sigma_y \bar{z}$ and $f(\min(c_i)) = f1(\min(c_i)) < f1(0) = f(0)$. Contradiction. It must be that $\min(c_i) = 0$.

Proof of Lemma 3.c**:** From the definition of two strategy equilibrium.

Market equilibrium:

We will show that the price depends only on z and the distribution of optimal cash holdings. Moreover the price increases in z.

If the cash available to surviving firms is greater than the measure of defaulted firms, the price is 1. If the cash available to surviving firms is less than the measure of defaulted firms multiplied by outsiders' valuation for a firm, the price is L. Otherwise the price is equal to cash available to surviving firms divided by the measure of defaulted firms.

Given that z increases both the survival probability of a firm and its available cash, an increase in z means an increase in available cash to survivors and a decrease in the measure of defaulted firms. Therefore the price increases in z, regardless of how much cash each firm holds. The assumption used in the previous section is confirmed.

Next, I use the results from previous section to derive the price function for the case when there are 2 groups of firms.

When $z < -\frac{\bar{c}+\mu}{\sigma_y}$ everybody defaults and $p = L$. When $z > -\frac{\mu}{\sigma_y}$ everybody survives and $p = 1$.

When $-\bar{c} < \mu + \sigma_y z < 0$ the price may depend on z. In this case the available cash to surviving firms is $\eta(\bar{c} + \mu + \sigma_y z)$ and the measure of defaulted firms is $1 - \eta$. The price is

$$\max\left(L, \min\left(\frac{\eta(\bar{c} + \mu + \sigma_y z)}{1 - \eta}, 1\right)\right)$$

Note that the pricing function $p(z)$ is continuous at $-\frac{\bar{c}+\mu}{\sigma_y}$, but it may have a jump at $-\frac{\mu}{\sigma_y}$ if $\frac{\eta\bar{c}}{1-\eta} < 1$. The monotonicity in z is confirmed again.

In case $\frac{\eta\bar{c}}{1-\eta} < 1$, $\mu + \sigma_y \bar{z} = 0$. Since $-c \geq 0 = \mu + \sigma_y \bar{z}$, the objective function $f(c) = f2(c)$ for any c. Given the equilibrium, it must be that both 0 and $\bar{c}$ are global maxima of $f(c)$. However $f2(c)$ has a unique maximum. Hence it cannot be that $\mu + \sigma_y \bar{z} = 0$. Therefore in equilibrium $\frac{\eta\bar{c}}{1-\eta} > 1$ and the pricing function $p(z)$ is continuous.

Numerical solution algorithm:

To derive the equilibrium solution I use the pricing function derived in Lemma 3. I can write for any c that satisfies $\frac{c+\mu}{\sigma_y} > -\underline{z} > -\bar{z}$:

$$f2'(c) = E_z\left[1_{\underline{z}>z>\frac{-c-\mu}{\sigma_y}}\left(\frac{1}{L}-1\right)+1_{\bar{z}>z>\underline{z}}\left(\frac{1-\eta}{\eta(\bar{c}+\mu+\sigma_y z)}-1\right)\right]+\frac{1}{\sigma_y}(1-L)\,\phi\left[\frac{c+\mu}{\sigma_y}\right]-\xi c=$$

$$=\left(N\left[\tilde{c}\right]-N\left[\tilde{\bar{c}}-La\right]\right)\left(\frac{1}{L}-1\right)+\int_{-\tilde{\bar{c}}+La}^{-\tilde{\bar{c}}+a}\left(\frac{a}{\tilde{\bar{c}}+z}-1\right)dN[z]+\frac{1}{\sigma_y}(1-L)\,\phi\left[\tilde{c}\right]-\xi c$$

Where $\tilde{c}\equiv\frac{c+\mu}{\sigma_y}$, $\tilde{\bar{c}}\equiv\frac{\bar{c}+\mu}{\sigma_y}$ and $a\equiv\frac{1-\eta}{\sigma_y\eta}$.

Set $c=\bar{c}$ and the equation $f2'(c)=0$ becomes:

$$0=-\xi c+\left(N\left[\tilde{c}\right]-N\left[\tilde{c}-La\right]\right)\left(\frac{1}{L}-1\right)+\int_{\tilde{c}-a}^{\tilde{c}-La}\left(\frac{a}{\tilde{c}-z}-1\right)dN[z]+\frac{1}{\sigma_y}(1-L)\,\phi\left[\tilde{c}\right] \quad (A3)$$

Take $c\geq 0$ as given and solve the equation above for $a^*(c)$ where $a^*(c)$ must satisfy $\frac{c}{\sigma_y} > a^*(c) > 0$. The right side strictly increases in a, hence there is maximum one solution. The proof uses that $\tilde{c}\geq\frac{c}{\sigma_y}\geq a$ and the derivative w.r.t. to a using Leibnitz rule.

In order to have a feasible solution $a^*(c)$ it must be that the right side for $a=0$ is negative and for $a=\frac{c}{\sigma_y}$ is positive. That means that c must be between c_1 and c_2 where c_1 is the solution to the equation when $a=0$ and c_2 is the solution when $a=\frac{c}{\sigma_y}$.

The second equilibrium condition states that $f2(c)=f1(0)$. Given that $\tilde{c}>-\bar{z}$ I get:

$$-E[1_{z<\bar{z}}(1-p(z))]=E\left[1_{-\tilde{c}<z<\bar{z}}(\tilde{c}+z)\sigma_y\left(\frac{1}{p(z)}-1\right)\right]-E[1_{z<-\tilde{c}}(1-p(z))]-\xi(c)$$

$$\xi(c)=E\left[1_{-\tilde{c}<z<\bar{z}}\left((\tilde{c}+z)\sigma_y\frac{1}{p(z)}+1\right)(1-p(z))\right]$$

$$\xi(c)=(1-L)E\left[1_{-\tilde{c}<z<\underline{z}}\left((\tilde{c}+z)\sigma_y\frac{1}{L}+1\right)\right]+E\left[1_{\underline{z}<z<\bar{z}}\frac{1}{\eta}\left(1-\frac{\eta\sigma_y(z+\tilde{\bar{c}})}{1-\eta}\right)\right]$$

Take $\bar{c}=c$ and the equation becomes:

$$\xi(c)=(1-L)E\left[1_{-\tilde{c}<z<\underline{z}}\left((\tilde{c}+z)\sigma_y\frac{1}{L}+1\right)\right]+E\left[1_{\underline{z}<z<\bar{z}}\frac{1}{\eta}\left(1-\frac{\eta\sigma_y(z+\tilde{c})}{1-\eta}\right)\right]$$

Explicitly:

$$\xi c^2/2=\frac{1-L}{L}\sigma_y\tilde{c}\left(N[\tilde{c}]-N[\tilde{c}-La]\right)+\frac{1-L}{L}\left(\phi[\tilde{c}]-\phi[\tilde{c}-La]\right)+$$

$$+\frac{1-a\tilde{c}}{\eta}\left(N[\tilde{c}-La]-N[\tilde{c}-a]\right)-\frac{\sigma_y}{1-\eta}\left(\phi[\tilde{c}-La]-\phi[\tilde{c}-a]\right) \quad (A4)$$

Take the solution $a^*(c)$ from $(A3)$ and replace it in $(A4)$. Solve for $c \in (c_1, c_2)$. By construction $c > \frac{1-\eta}{\eta}$.

The equilibrium in case when project financing is allowed for surviving firms

Starting from the setup described in Section 3.1, I relax the 'no external financing' assumption. Namely, the surviving firms at $t = 1$ are allowed to borrow α to finance the purchase of each unit of a productive asset. That is to say firms are allowed to pledge α of the $t = 2$ cashflow of the newly acquired assets in order to finance the purchase.

The pricing function described in Lemma 1 and 2 is unchanged. The firm problem (3) becomes:

$$\max_{c\geq 0} f(c,p) = E_F\left[1_{F+c>0}\left(1+\frac{(F+c)(1-\alpha)}{p-\alpha}\right)+1_{F+c<0}(F+c+p)\right]-\xi(c)-c$$

$$\max_{c\geq 0} f(c,p) = E_z\left[\left(N\left[\frac{c+\mu+\sigma_y z}{\sigma_x}\right](c+\mu+\sigma_y z)+\phi\left[\frac{c+\mu+\sigma_y z}{\sigma_x}\right]\sigma_x\right)\frac{1-p(\mathcal{F}_1)}{p(\mathcal{F}_1)-\alpha}- \right.$$
$$\left. -\left(1-N\left[\frac{c+\mu+\sigma_y z}{\sigma_x}\right]\right)(1-p(\mathcal{F}_1))\right]+\mu+1-\xi(c) \qquad (A5)$$

Thus the only change from the previous equilibrium is the $p - \alpha$ term instead of p. To keep the analysis simple, I assume that $L > \alpha$, thus $p > \alpha$ in all states.

The solution to the equilibrium follows the same pattern as for the base case. Figure 4 illustrates the comparative statics of the solution to symmetric equilibrium w.r.t. L and σ_y.

Appendix B - Empirical Tests

Data filters

Only entries that have non-missing values for NAICS code, debt and net working capital are kept. Further, cash/net assets must be between 0 and 1.5, M/B must be between 0 and 10, assets and sales must be higher than $1 mil, share price must be higher than $1 and the firm must have more than $100,000$ shares. The limitations on cash and MB are placed in order to avoid outliers driving the results. In case there are missing data for R&D, acquisitions, capex, intangibles, machinery and equipment or cash dividends, they are considered 0.

For each firm I require at least 3 valid observations. To distinguish between firms and industries I require for each industry at least 8 valid firms and 100 valid observations. After all filters there are 88243 observations and 115 industries left. To compute spreads in cash, for each industry I consider only the years where there are at least 7 firms in order to have at least 5 observations left after winsorizing. Further, I keep only the industries that have at least 8 years with at least 7 observations. This reduces the number of industries to 99 in tests of hypothesis 2.

Figure 1. Theoretical Determinants Of Industry Cash

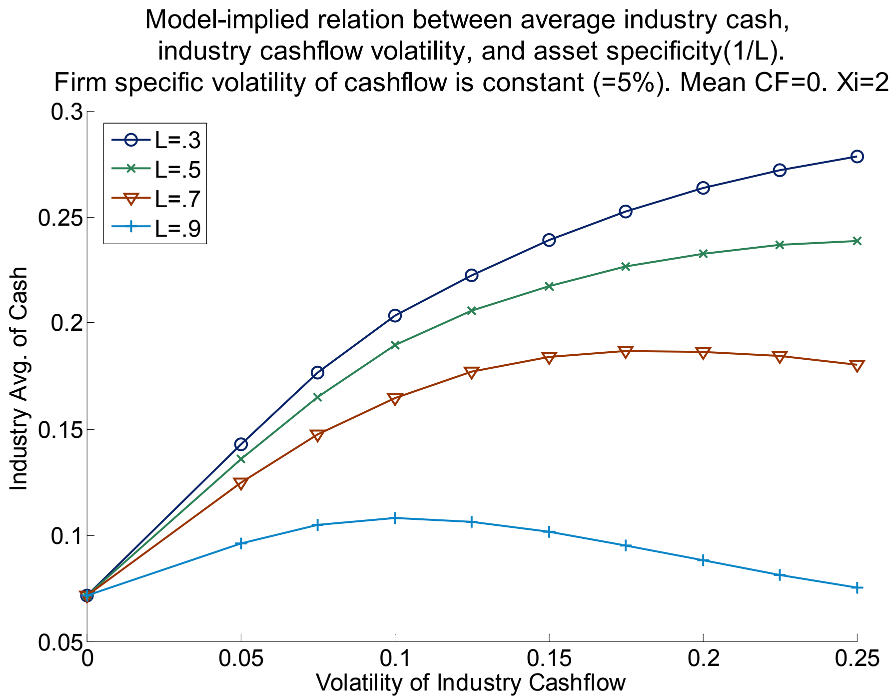

Figure 2. Intra-Industry Variability Of Optimum Cash

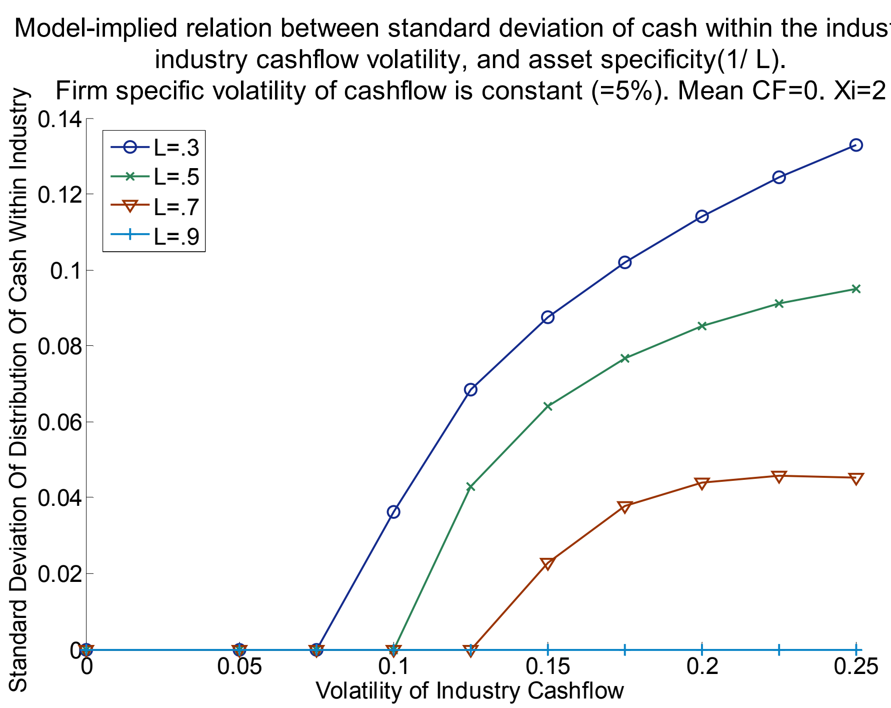

Figure 3. Industry Patterns in Cash—No Idiosyncratic Uncertainty

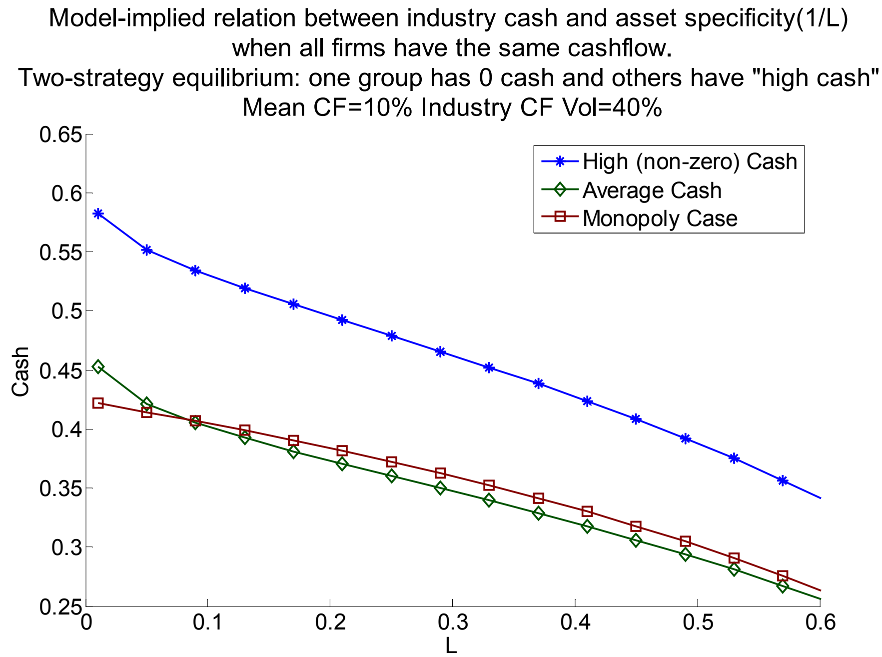

Figure 4. Determinants of Industry Cash When Project Financing Is Allowed

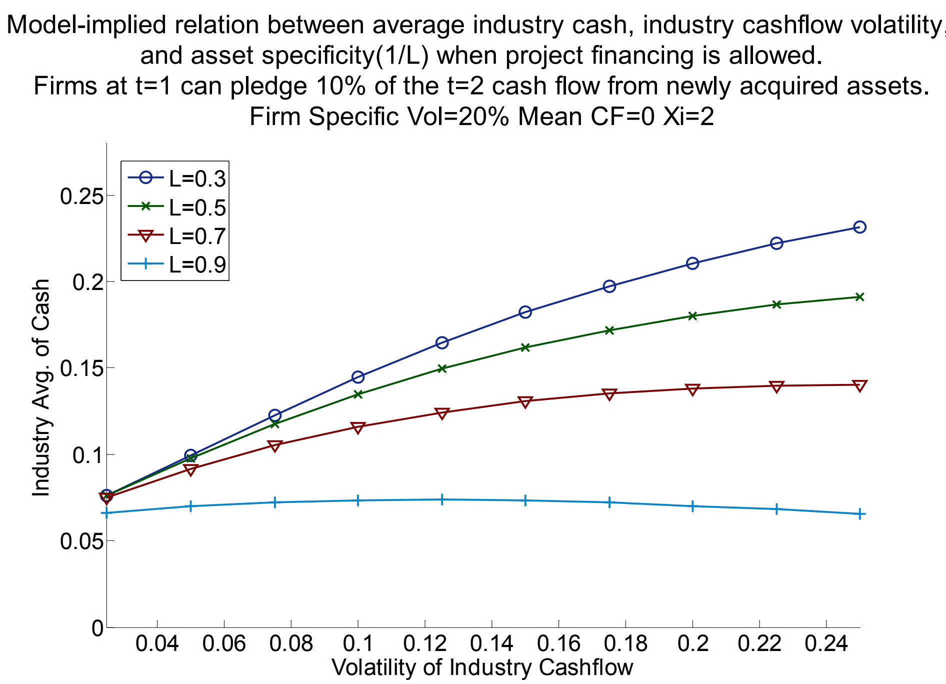

Table 1. Summary Statistics and Correlations

Panel A: Summary statistics of firm specific variables

Variable	N	Mean	Std Dev	1^{st} Pctl	50^{th} Pctl	99^{th} Pctl
Cash/Net Assets	89188	0.170	0.251	0.000	0.067	1.243
Age	89188	15.110	11.553	1	12	49
M/B	89188	1.635	1.172	0.578	1.246	6.785
Log Size	89188	5.272	1.977	1.396	5.107	10.205
Book Debt/Assets	89188	0.229	0.174	0	0.216	0.691
ST Debt/Assets	89188	0.057	0.083	0	0.026	0.398
LT Debt/Assets	89188	0.172	0.155	0	0.148	0.626
R&D Exp/Sales	89188	0.045	0.255	0	0	0.471
Capit R&D/Net Assets	89188	0.076	0.125	0	0.006	0.563
Working Cap/Net Assets	89188	0.212	0.207	-0.326	0.216	0.655
Capex/Net Assets	89188	0.078	0.071	0	0.059	0.354
Acquisitions/Net Assets	89188	0.019	0.066	0	0	0.333
Divid. Dummy	89188	0.564	0.496	0	1	1
LT Debt/Book Debt	89188	0.647	0.345	0	0.788	1
Tangibility	89188	0.334	0.198	0.027	0.301	0.873
M&Eq/Net Assets	89188	0.143	0.146	0	0.118	0.653
Intangibles/Net Assets	89188	0.066	0.129	0	0.002	0.629
Cash Flow/Net Assets	89188	0.078	0.217	-0.688	0.097	0.408
Firm Cash Flow Vol	89188	0.074	0.061	0.014	0.058	0.315
Cash Cycle	89188	10.313	37.561	-30.734	-2.551	115
Cash Cycle Vol	89188	6.418	9.561	0.920	3.502	64.551

Panel B: Summary statistics of industry level variables:
cash, asset specificity proxies, cash flow volatility, spread in cash

Variable	N	Mean	Std Dev	Minimum	50^{th} Pctl	Maximum
Avg. Cash	115	0.080	0.055	0.027	0.068	0.451
Ind Dummy	115	0.175	0.044	0.099	0.167	0.406
Cash Flow Vol	115	0.032	0.023	0.009	0.027	0.181
AS Segments	115	0.540	0.166	0.141	0.534	0.913
AS M/B	115	1.473	0.456	0.919	1.323	3.212
AS Capit R&D+Intangib	115	0.136	0.092	0.006	0.123	0.447
Cash Spread	99	23.52	9.57	9.42	21.61	62.04

Panel C: Correlation among cash, asset specificity proxies and cashflow volatility.

	Avg. Cash	Ind. Dum.	CF Vol	AS Segm.	AS M/B	AS R&D+I
Avg. Cash		0.778	0.372	0.413	0.617	0.388
Ind Dummy	0.778		0.265	0.297	0.604	0.520
Cash Flow Vol	0.372	0.265		0.085	0.174	0.251
AS Segments	0.413	0.297	0.085		0.439	0.213
AS M/B	0.617	0.604	0.174	0.439		0.455
AS Capit R&D+Intangib	0.388	0.520	0.251	0.213	0.455	

Table 2. Stage 1 Results: Models of cash and net debt

Table reports the estimation results of the cash and net debt models based on Arellano-Bond Anderson-Hsiao methodology. This is the Stage 1 described in text. In model 1 the dependent variable is $Cash/(BookAssets - Cash)$ and in model 2 it is $(Debt - Cash)/(BookAssets - Cash)$. $CashFlow$ is treated as predetermined. Annual dummies, industry dummies, $CFVol$ and $CashCycleVol$ are treated as exogenous. All other variables are treated as endogenous. The procedure has 3 steps: (1) de-trend the data by regressing the dependent variable on $Ln(Age)$; (2) obtain consistent estimates of coefficients on time-varying variables by using the Arellano-Bond methodology on de-trended data using three lags as instruments; (3) obtain estimates of coefficients on time-invariant variables by regressing the residuals from previous step on the time-invariant variables (industry dummies, $CFVol$ and $CashCycleVol$). From the AB procedure, I report (*a*) the test for second order autocorrelation in the first-difference of errors; and (*b*), the Wald test whether all coefficients are 0. I report the correlation between actual and fitted values, which are computed using all variables, with and without industry dummies ($\hat{Y}_{all}$ and $\hat{Y}_{no\ ind}$). Standard errors at step 2 are computed using the robust GMM estimator allowing for cross-sectional correlation in errors. Standard errors at other steps are computed using White estimator. T-stats in parenthesis.

Variable	Cash/Net Assets	(Debt-Cash)/Net Assets
Log Age	-0.044	0.042
	(-42.9)	(28.9)
Lag Cash	0.390	
	(33.2)	
Lag Debt-Cash		0.463
		(43.0)
M/B	0.008	-0.009
	(2.8)	(-2.6)
Log Size	-0.027	0.107
	(-3.2)	(10.4)
Short Term Debt	-0.507	
	(-10.1)	
Long Term Debt	-0.036	
	(-1.6)	
LT Debt/Debt	-0.003	
	(-0.2)	
R&D	-0.034	0.030
	(-1.0)	(0.8)
Working Capital	-0.294	0.295
	(-9.0)	(6.4)
Capex	-0.322	0.516
	(-7.4)	(8.4)

Table 2. (cont.) Stage 1 Results

Variable	Cash/Net Assets	(Debt-Cash)/Net Assets
Acquisitions	-0.450	0.725
	(-6.7)	(8.7)
Dividend Dummy	-0.003	-0.005
	(-0.5)	(-0.7)
Machin.&Equipm.	-0.089	0.150
	(-3.2)	(4.3)
Intangibles	-0.162	0.199
	(-4.2)	(3.8)
Cash Cycle	0.000	0.000
	(0.2)	(1.1)
Cash Flow	0.071	-0.130
	(3.2)	(-4.5)
Tangibility		0.120
		(2.3)
Cash Flow Vol.	0.721	-0.974
	(28.6)	(-30.2)
Cash Cycle Vol.	0.001	-0.002
	(6.6)	(-12.4)
Annual dummies	Y	Y
Industry dummies	Y	Y
Test 2^{nd} order autocorr in $\Delta\epsilon$	0.29	0.88
p-val	0.77	0.38
Wald χ^2 p-val	0.000	0.000
$Corr^2(Y, \hat{Y}_{no\ ind})$	0.110	0.096
$Corr^2(Y, \hat{Y}_{all})$	0.188	0.197
Obs	72086	72086

Table 3. Industry average of cash holdings: The effects of firms' strategic interaction

Table reports the main tests of average cash holdings hypothesis. I expect cash to be positively related to asset specificity and the product between asset specificity and industry cashflow volatility. The dependent variable is 100∗ the set of industry dummy coefficients from Stage 1. Asset specificity measures are described in text. "Pr Comp" is the principal component of all three measures of asset specificity. The first set of results uses raw measures for explanatory variables, while the second set uses derived rank measures, with ranks from 1 to 10. For rank measures, "Pr Comp" is replaced by the average over the three ranks. Raw measures are scaled to 0 mean and unit variance, thus the coefficients on individual variables represent the marginal effects of a unit standard deviation increase given that the other variable is at the mean. Rank measures are de-meaned, thus the coefficients on individual variables represent the marginal effects of a unit rank increase given that the other variable is at the mean. Herfindahl index is from Compustat. Each regression includes an intercept, not reported. The t-statistics are in parenthesis. Estimation is done through WLS where the weights are the inverse of the variance of dummy coefficient estimates. The estimates of the variance are obtained at stage 1.

	Raw A.S. Measures							Rank A.S. Measures			
	1	2	3	4	5	6	7	1	2	3	4
Industry CF Vol	0.02	0.10	0.34	0.05	0.35	0.21	0.58	0.16	**0.24**	0.20	**0.23**
	(0.0)	(0.2)	(0.7)	(0.1)	(0.6)	(0.4)	(1.2)	(1.3)	**(2.2)**	(1.8)	**(2.2)**
A.S. Segments	**1.26**				**1.35**			**0.43**			
	(3.7)				**(3.6)**			**(3.7)**			
A.S. M/B		**2.43**				**2.49**			**0.75**		
		(8.2)				**(8.1)**			**(7.3)**		
A.S. CapitR&D+Intang			**2.50**				**2.55**			**0.75**	
			(8.3)				**(8.6)**			**(7.5)**	
A.S. Pr Comp (Avg Rank)				**2.54**							**1.06**
				(9.1)							**(8.3)**
Segm*CF Vol	**1.48**				**1.47**			**0.15**			
	(2.9)				**(2.9)**			**(3.6)**			
M/B*CF Vol		**0.85**				**0.92**			**0.07**		
		(2.3)				**(2.2)**			**(2.1)**		
RD&Intang*CF Vol			0.10				-0.08			0.04	
			(0.3)				(-0.2)			(1.3)	
Pr Comp*CF Vol				0.48							**0.10**
				(1.5)							**(2.3)**
Herfindahl					-0.13	-0.27	-0.52				
					(-0.3)	(-0.7)	(-1.3)				
Adj. Rsq	16%	40%	41%	45%	15%	40%	42%	15%	33%	34%	39%
Obs	115	115	115	115	115	115	115	115	115	115	115

Table 4. Intra-industry variability of cash holdings: The effects of firms' strategic interaction

Table reports the main tests of intra-industry variability of cash hypothesis. I expect the range in cash to be positively related to asset specificity and industry cashflow volatility. The dependent variable is 100∗ the difference between Stage 1 1%-winsorized residuals in quintile 1 and quintile 5 in each industry, as described in text. Asset specificity measures are described in text. "Pr Comp" is the principal component of all three measures of asset specificity. The first set of results uses the raw measures for explanatory variables, while the second set uses derived rank measures, with ranks from 1 to 10. For rank measures, "Pr Comp" is replaced by the average over the three ranks. Raw measures are scaled to 0 mean and unit variance, thus the coefficients represent the effects of a unit standard deviation increase. Rank measures are de-meaned, thus the coefficients represent the effects of a unit rank increase. Each regression includes an intercept, not reported. The t-statistics are in parenthesis. Estimation is done through OLS and errors are obtained using White's estimator.

	Raw A.S. Measures				Rank A.S. Measures			
	1	2	3	4	1	2	3	4
Industry CF Vol	**3.64**	**2.93**	**2.92**	**2.35**	**0.97**	**0.87**	**1.00**	**0.89**
	(5.0)	**(5.8)**	**(4.4)**	**(4.7)**	**(2.7)**	**(2.9)**	**(3.0)**	**(3.4)**
A.S. Segments	**3.61**				**1.49**			
	(3.8)				**(3.8)**			
A.S. M/B		**5.29**				**2.16**		
		(4.9)				**(5.8)**		
A.S. CapitR&D+Intang			**4.65**				**1.83**	
			(3.9)				**(4.9)**	
A.S. Pr Comp (Avg Rank)				**6.25**				**3.45**
				(8.3)				**(7.2)**
Adj. Rsq	32%	47%	40%	57%	21%	38%	28%	49%
Obs	99	99	99	99	99	99	99	99

Table 5. Robustness checks of the results about industry average cash hypothesis

Table reports the complementary tests of average cash holdings hypothesis. The results to the main tests (base case) are given in Table 3, left side. In the first set of tests I use an adjusted measure of industry cashflow volatility, which I obtain by excluding the market cashflow volatility via a market model. For the second set of results, I run the tests at each point in time and then aggregate the time-series of coefficients by fitting a regression with autocorrelated errors (maximum likelihood estimation) and only an intercept as explanatory variable. For each variable, I report the coefficients on the intercept and their t-statistics. For the annual regressions, I obtain the annual set of industry dummies by estimating the last step of Stage 1 separately for each year. Moreover, I compute the asset specificity measures each period, while cashflow volatility remains constant over time. The third set of results uses a sample without conglomerates, to obtain the industry dummies coefficients at Stage 1. After that step the methodology is unchanged from the base case. For all sets of results, all explanatory variables are scaled to 0 mean and unit variance. Each regression includes an intercept, not reported. The t-statistics are in parenthesis. For the first and third set of results estimation is done through WLS, where the weights are the inverse of the variance of dummy coefficient estimates.

	Adjusted Cashflow Vol.				Time-Series Tests				No Conglomerates			
Variable	1	2	3	4	1	2	3	4	1	2	3	4
Industry CF Vol	0.28	0.06	0.14	-0.06	0.40	0.19	-0.01	0.44	-0.01	0.28	1.22	-0.08
	(0.6)	(0.1)	(0.3)	(-0.1)	(1.4)	(0.4)	(-0.0)	(1.6)	(-0.0)	(0.4)	(1.6)	(-0.1)
A.S. Segments	**1.38**				**1.84**				**3.00**			
	(3.9)				**(4.4)**				**(4.8)**			
A.S. M/B		**2.52**				**1.93**				**3.77**		
		(8.3)				**(5.1)**				**(6.8)**		
A.S. CapitR&D+Intang			**2.56**				**1.87**				**3.51**	
			(8.5)				**(6.0)**				**(6.1)**	
A.S. Pr Comp				**2.63**				**3.05**				**4.56**
				(9.3)				**(6.1)**				**(9.6)**
Segm*CF Vol	**1.51**				**2.04**				**2.44**			
	(3.1)				**(5.1)**				**(3.0)**			
M/B*CF Vol		**0.98**				**0.83**				**1.71**		
		(2.5)				**(1.9)**				**(2.5)**		
RD&Intang*CF Vol			0.06				0.19				0.15	
			(0.2)				(0.6)				(0.2)	
Pr Comp*CF Vol				0.59				**1.32**				**1.15**
				(1.7)				**(3.2)**				**(2.2)**
Adj. Rsq	14%	39%	41%	44%	NA	NA	NA	NA	25%	37%	32%	53%
Obs	115	115	115	115					98	98	98	98

Table 6. Industry distribution of net debt: The effects of firms' strategic interactions

Table reports the tests of industry net debt hypothesis and, respectively, of spread in net debt hypothesis. The tests follow the same methodology as in the case of cash. I expect that average net debt in the industry is negatively related to asset specificity and the interaction between asset specificity and industry cashflow volatility. Moreover, the intra-industry variability of net debt is positively related to asset specificity and cashflow volatility. When testing the first hypothesis, the dependent variable is the set of industry dummy coefficients from Stage 1. For tests of the second one, the dependent variable is the difference between net debt residual of firms in quintile 1 and of firms in quintile 5 within an industry. All explanatory variables have been scaled to 0 mean and variance 1. Each regression includes an intercept, not reported. The t-statistics are in parenthesis. Estimation for "Average Industry Net Debt" is done through WLS where the weights are the inverse of the variance of dummy coefficient estimates. Estimation for "Intra-Ind. Variab. of Net Debt" is done through OLS, where errors are adjusted using White's estimator. The first set of results can be compared with the results for cash from Table 3, left side. The second set of results can be compared with the results for cash from Table 4, left side.

	Average Industry Net Debt				Intra-Ind. Variab. of Net Debt			
	1	2	3	4	1	2	3	4
Industry CF Vol	0.11	-0.47	**-2.11**	-0.66	**3.48**	**2.83**	**2.68**	**2.13**
	(0.1)	(-0.5)	**(-1.9)**	(-0.6)	**(4.1)**	**(4.3)**	**(3.4)**	**(3.3)**
A.S. Segments	**-1.91**				**4.01**			
	(-2.6)				**(3.5)**			
A.S. M/B		**-4.82**				**5.29**		
		(-8.2)				**(4.8)**		
A.S. CapitR&D+Intang			**-5.08**				**5.20**	
			(-8.6)				**(4.4)**	
A.S. Pr Comp				**-4.79**				**6.66**
				(-8.3)				**(7.5)**
Segm*CF Vol	**-2.57**							
	(-2.5)							
M/B*CF Vol		-0.95						
		(-1.3)						
RD&Intang*CF Vol			0.88					
			(1.3)					
Pr Comp*CF Vol				-0.33				
				(-0.5)				
Adj. Rsq	13%	41%	45%	42%	21%	28%	27%	38%
Obs	115	115	115	115	99	99	99	99

Table 7. The effects of asset specificity on the decrease in price of assets during industry downturns

Table reports the tests of the hypothesis about the effects of asset specificity on the price of productive assets. For transactions between firms from the same industry, I expect that the decrease during industry downturns vs. upturns in the price-to-book (p/b) is positively related to the asset specificity of the industry. The columns labeled "Sales to insiders" report the results of the OLS regression where the dependent variable is the difference between average p/b for sales to insiders (both party are from the same industry) over the years when industry is in an upturn, and the average p/b for sales to insiders over the years when industry is in a downturn. The industry is in a downturn if the inflation-adjusted industry cashflow is negative. Moreover, for transactions between firms from different industry, I expect that the decrease during industry downturns vs. upturns in the p/b is unrelated to the asset specificity of the industry. The columns labeled "Sales to outsiders" report the results of the OLS regression where the dependent variable is the difference between average p/b for sales to outsiders (parties are from different industries) over the years when industry is in an upturn, and the average p/b for sales to insiders over the years when industry is in a downturn. The asset specificity proxies are scaled to unit variance and are described in text. T-stats in parenthesis. All tests include an unreported intercept.

	Sales to insiders			Sales to outsiders		
	1	2	3	1	2	3
A.S. Segments	0.31			0.62		
	(0.9)			(1.7)		
A.S. M/B		**0.96**			0.06	
		(2.9)			(0.2)	
A.S. CapitR&D+Intang			**0.86**			-0.02
			(3.0)			(-0.1)
Adj. Rsq	0%	12%	13%	3%	-2%	-2%
Obs	54	54	54	61	61	61

Table 8. The effects of the decrease in price of assets during industry downturns on the average industry cash

Table reports the tests of the hypothesis about the connection between asset specificity, the price of productive assets, and average industry cash. For transactions between firms from the same industry, I expect that the decrease during industry downturns vs. upturns in the price-to-book (p/b) is positively related to the average industry cash. Further, this relation exists because both variables depend on asset specificity, thus when the the exogenous variables are added in, the relation should disappear. The dependent variable is the set of coefficients on the industry dummies from Stage 1. The explanatory variable "Decrease in price for insiders" is constructed as the difference between average p/b for sales to insiders (both party are from the same industry) over the years when industry is in an upturn, and the average p/b for sales to insiders over the years when industry is in a downturn. The industry is in a downturn if the inflation-adjusted industry cashflow is negative. The asset specificity proxies and industry cashflow volatility are scaled to mean 0 and unit variance and are described in text. Estimation is done through WLS where the weights are the inverse of the variance of dummy coefficient estimates. T-stats in parenthesis. All tests include an unreported intercept.

	1	2	3	4
Decrease in price for insiders	**0.50**	**0.52**	0.08	0.28
	(2.5)	**(3.0)**	(0.5)	(1.5)
Industry Cashflow Volatility		0.49	0.35	0.93
		(0.5)	(0.6)	(1.3)
Asset Specificity: Segments		**1.28**		
		(2.7)		
Asset Specificity: M/B			**3.24**	
			(6.3)	
Asset Specificity: CapitR&D+Intang				**1.93**
				(3.6)
AS Segments*Ind CFVol		1.26		
		(1.5)		
AS MB*Ind CFVol			0.42	
			(1.0)	
AS CapitRD&Intang*Ind CFVol				0.04
				(0.1)
Adj. Rsq	9%	37%	60%	42%
Obs	50	50	50	50