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Debt, Liquidity Constraints, and Corporate Investment: Evidence from Panel Data

TONI M. WHITED*

ABSTRACT

This paper presents evidence supporting the theory that problems of asymmetric information in debt markets affect financially unhealthy firms' ability to obtain outside finance and, consequently, their allocation of real investment expenditure over time. I test this hypothesis by estimating the Euler equation of an optimizing model of investment. Including the effect of a debt constraint greatly improves the Euler equation's performance in comparison to the standard specification. When the sample is split on the basis of two measures of financial distress, the standard Euler equation fits well for the *a priori* unconstrained groups, but is rejected for the others.

DO IMPERFECTIONS IN THE financial system play a role in economic fluctuations? Recent research in empirical macroeconomics has directed this question to the area of investment, asking in particular whether firms with free access to capital markets have different investment behavior from those who do not. Emphasis on this question has resulted in part from the theoretical predictions of a recent surge of work in the economics of imperfect information that has explored how violations of the Modigliani-Miller theorem ascribe a role for financial factors in the investment process. In addition, interest in the question has been spurred by the poor empirical performance of standard optimizing models of investment. For example, tests of the *q*-theory of investment have found little explanatory power for *q*, have implied implausibly slow capital stock adjustment speeds, and have been outperformed by simple *ad hoc* accelerator models.¹

One specific hypothesis has been at the center of recent attempts to explore the connection between finance and investment. If a firm has difficulty obtaining outside finance, its investment should display excess sensitivity to the availability of internal funds.² Moreover, differences in this sensitivity

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¹ See, for example, Blanchard and Wyplosz (1981), Summers (1981), Poterba and Summers (1983), Abel and Blanchard (1986), and Abel (1990).

² See Fazzari and Athey (1987), Fazzari, Hubbard, and Petersen (1988a, 1988b), and Hoshi, Kashyap, and Scharfstein (1990, 1991).

should be evident across different classes of firms. Although tests of this proposition have been supportive, they rely on reduced-form regressions of investment on q , cash flow, and, in some cases, output. They therefore suffer not only from the well-known divergence of measured average q from marginal q , but from a number of alternative interpretations. In particular, cash flow may not be picking up the desired liquidity effect but may be proxying either for an accelerator effect or for information about future investment opportunities not captured by q .

This paper addresses the question of the interdependence of finance and investment from a different angle, by using the Euler equation of a structural model of investment to isolate the precise role of finance constraints in the investment process.³ This approach has been used in a similar fashion in the consumption literature. In particular, Zeldes (1989) finds that the consumption Euler equation fails for low-wealth consumers and that it holds for high-wealth consumers. As applied to investment, the Euler equation methodology complements previous studies in that it exploits the cross-sectional heterogeneity among different firms to test for the role of financial factors. However, it avoids many of the pitfalls associated with estimating reduced-form investment equations. In addition, it points out the specific impact of financial factors on the intertemporal allocation of investment.

The paper also extends the work by Fazzari et al. (1988a, 1988b) by concentrating on debt instead of equity finance. This emphasis is, in part, a response to the observation that for most firms debt is a more important source of incremental funding than outside equity. A number of studies indicate that share issues typically account for less than 5% of total new external finance.⁴ In a loose sense, if debt is the primary *marginal* source of external funds, then the potential is great for credit restrictions to affect corporate decisions.

The basic premise of the paper stems from one of the canonical predictions of asymmetric information theory, that small firms with low liquid asset positions have limited access to debt markets, presumably because they lack the collateral necessary to back up their borrowing.⁵ In the context of a standard neoclassical model of investment, this idea implies that a firm that faces a borrowing constraint today will tend to behave as if it has a high and variable discount rate. Two major implications emerge from this idea. First, financial variables should enter directly into the Euler equation through their effect on the Lagrange multiplier on a constraint restricting debt

³ See Abel (1980) and Shapiro (1986) for earlier studies that estimate investment Euler equations.

⁴ See, for example, Friedman (1982), Srinivasan (1986), and Fazzari et al. (1988a, 1988b). These calculations are made with flow variables. However, measured as a stock, a typical firm's equity to assets ratio is much greater than 5%. This discrepancy occurs because internal equity (i.e., retained earnings) contributes to the stock. See Bernanke and Campbell (1988) and Bernanke, Campbell, and Whited (1990).

⁵ For reviews of this literature see Myers (1984) and Gertler (1988).

issuance. This constraint in turn influences the firm's discount rate. Such a specification allows for the estimation of the cross-sectional divergence of individual firm discount rates not directly available in the data. Second, the investment Euler equation of the standard neoclassical model should hold across adjacent periods for a priori unconstrained firms but be violated for constrained firms. For this latter group of firms a wedge should exist between the marginal cost of investment today versus investing tomorrow. This wedge corresponds to the effect of financial factors on the discount rate, which the standard model does not take into account.

The results generally support the view that a firm's financial position affects its investment. The first test uses the full sample to estimate the extent to which different measures of financial distress affect a firm's allocation of investment expenditure. Two indicators are used: (1) the market value of debt relative to the market value of the firm, and (2) the ratio of interest expense to the sum of interest expense and cash flow. Within the Euler equation framework derived from the model, I estimate values of the Lagrange multiplier on a constraint restricting debt issue. The explanatory variables enter the equation with the right sign, and most are significant. Also, the implied values of the Lagrange multiplier are fairly reasonable.

The second set of tests stems first from dividing the sample separately on the basis of each of these indicators. For the a priori constrained groups the simple Euler equation governing investment is strongly rejected, while for the unconstrained group it fares much better. In addition, the effects of financial variables in an augmented version of the Euler equation are significant for the financially unhealthy firms but not for those in good financial health. I also divide the sample on the basis of whether the firm has a bond rating at the beginning of the sample period or not. The idea here is that firms that use the corporate bond market have undergone more investor scrutiny so that they are less affected by informational asymmetries. For both groups of firms the standard equation is strongly rejected. However, the one-period discount rate responds more strongly to the financial variables for the group without bond ratings.⁶

The rest of the paper is organized as follows. Section I provides an overview of some of the theoretical reasons for a role for liquidity in the investment process. In Section II I present a model of finance and investment with and without borrowing constraints. Section III describes the econometric tests and Section IV the data. Because testing these implications involves observing different groups of individual firms over time, I use as my primary data source the COMPUSTAT industrial file, a large panel of U.S. corporations. Section V presents the results. Concluding remarks and directions for further research are provided in the last section.

⁶ A series of more recent papers has corroborated these results. See Gilchrist (1990) and Himmelberg (1990) for studies using firm panel data, and Hubbard and Kashyap (1990), which uses aggregate agricultural data.

I. Debt Market Imperfections and the Cost of External Funds

If all borrowers and lenders are risk neutral and if debt markets are perfect, then all interest rates on similar maturity debt should be equal. However, if a firm has better information over its investment opportunities and its actions than do potential investors, then its cost of borrowing may increase relative to the cost faced by a firm not plagued by such information asymmetries—perhaps to the extent that it cannot obtain credit at all. A number of recent theoretical papers have studied this possibility. Their underlying theme is that informational asymmetries may induce financial market inefficiencies that spill over to the real side of the economy. More specifically, the usual result in models of one-period contracting is that low levels of financial assets will increase the agency costs of outside finance and therefore increase the opportunity cost of investment. The rest of this section examines in more detail some of the main arguments along this line.

The incentive effects of debt contracts can raise the cost or availability of borrowing in two important ways. First, Myers (1977) presents a model based on this idea, in which high levels of debt cause firms to forgo projects with positive net present value. Using debt creates the potential for underinvestment and bankruptcy, which lowers the equilibrium value of the firm. This effect can be viewed as an agency cost of debt. Myers also allows for a role for internal net worth by showing that if tangible assets are small relative to future investment opportunities, this drop in value will be more likely to occur, since a greater portion of firm value rests on the option of future expansion.

Jensen and Meckling (1976) also invoke a moral hazard argument to explain the agency costs of debt, proposing that high levels of debt will induce firms to opt for excessively risky investment projects. The incentive for such a move is that limited liability provisions in debt contracts imply that risky projects will provide higher mean returns to the shareholders: zero in low states of nature and high in good states. However, the higher probability of default will induce investors to demand either interest rates premiums or bond covenants that restrict the firm's future use of debt.

The problem of adverse selection can also contribute to the cost of debt finance. Myers and Majluf (1984) use a variant of Akerlof's (1970) "lemons" model to argue that if managers have private information about their investment projects, they may have to obtain external finance at a premium in order to compensate investors for the possibility of funding a "bad" firm, whose projects may have a negative net present value.⁷ In addition, they show that a firm will always prefer debt to equity, since debt dominates equity in terms of minimizing this "lemons" problems. By issuing a security with a non-contingent repayment and bankruptcy provisions, such as debt,

⁷ Leland and Pyle (1977) and Greenwald, Stiglitz, and Weiss (1984) propose similar arguments. The latter notes that such a problem with new equity issues may prevent firms constrained in debt markets from finding alternative sources of funds.

the firm signals to investors that it may be “good,” since it is willing to assume some of the consequences of its investment decisions. A high level of net worth will also convey positive information to potential debt holders.

Finally, the idea that it may be expensive to make securities fully state-contingent can account for the existence of debt contracts as well as the differential availability of external versus internal finance.⁸ If a lender must pay or exert effort to observe a firm’s return on a project, then it will minimize this cost by using a contract that depends on the return and thus requires the lender to observe the outcome of the firm’s project only if the firm cannot repay; that is, a debt contract. If the firm has low levels of financial assets, it will be more likely to go bankrupt. This problem will raise the lender’s expected observation costs, thus forcing him to charge a higher interest rate or restrict credit altogether.

II. A Dynamic Model of Finance and Investment

I motivate my empirical work by using a standard model of finance and investment developed in the public finance and investment literatures to derive a set of Euler equations governing the evolution of investment and the capital stock. One goal of this paper is to determine whether the empirical failure of much of the previous work on investment is due to financial market imperfections or to other auxiliary assumptions. Therefore, I then modify the model to account for these frictions by incorporating a limit on the amount of debt a firm may have outstanding in any one period; and I derive a new set of Euler equations.⁹

A. The Model without a Credit Limit

A number of simplifications are required to make the basic model tractable. First, in order to isolate the role of debt finance, I do not explicitly model the issue of new shares. This approach helps focus on the effects of restrictions on outside debt by eliminating the possibility of a financial hierarchy in which firms prefer to raise funds through retained earnings rather than through new shares issues.¹⁰ The owners and managers of the firm are risk neutral, and the managers act on behalf of the stockholders in order to maximize the value of the firm. The model is a partial equilibrium one in the sense that the behavior of the financial sector is taken as exogenous. Also, at any time t , all present variables are known to the firm with certainty, though all future variables are stochastic. Finally, managers are assumed to have rational expectations.

⁸ Townsend (1979) is the seminal reference. See also Gale and Hellwig (1985) and Bernanke and Gertler (1989, 1990).

⁹ The limit can be interpreted loosely either as a literal credit constraint or as an interest rate premium, since both interpretations lead to the same qualitative conclusions and results.

¹⁰ Mackie-Mason (1987) finds weak evidence rejecting the idea of a financial hierarchy and reviews the inconclusive literature on its existence.

The analysis of investment demand must begin with an expression for the value of the firm, which in turn stems from the arbitrage condition governing the valuation of shares. The net after-tax return to the owners of firm i at time t comprises current dividends and capital appreciation. In equilibrium, if the owners are to be content holding their shares, this return must equal their required after-tax return, R_{it} .

$$\frac{(E_t V_{i,t+1} - V_{it}) + E_t d_{i,t+1}}{V_{it}} = R_{it}, \quad (1)$$

where V_{it} is the value of firm i at time t ; $d_{i,t+1}$ is the after-tax dividends of the firm at time $t + 1$; and E_t is the expectation conditional on information known at time t . This specification implies that today's dividends are paid out at the beginning of next period. The term in parentheses, which represents the capital gain component of the return, should be thought of as net of taxes.

In the absence of any bubbles, solving this equation forward yields the following expression for the firm's time zero market value:

$$V_{i0} = E_0 \sum_{t=0}^{\infty} \left[\prod_{j=0}^{t-1} \beta_{ij} \right] d_{it}. \quad (2)$$

Here, $\beta_{ij} = 1/(1 + R_{ij})$, that is, the firm's discount factor. The value of the firm is simply the present discounted value of the expected after-tax dividend stream. The firm maximizes its market value subject to four constraints. The first is the capital stock accounting identity:

$$K_{it} = I_{it} + (1 - \delta)K_{i,t-1}. \quad (3)$$

Here, K_{it} is the capital stock of firm i at the end of time t , I_{it} is its investment at time t , and δ is the constant rate of economic depreciation.

The second constraint defines the firm's dividends. Cash inflows include sales and net borrowing, while cash outflows consist of dividends, factor and interest payments, and investment expenditures. This constraint can thus be written as:

$$\begin{aligned} d_{it} = & (1 - \tau)(F(K_{i,t-1}, N_{it}) - w_t N_{it} - \psi(I_{it}, K_{i,t-1}) - i_{t-1} B_{i,t-1}) \\ & + B_{it} - (1 - \pi_t^e) B_{i,t-1} - p_{it} I_{it}, \end{aligned} \quad (4)$$

where:

- N_{it} = a vector of variable factors of production for firm i at time t ,
- w_t = a vector of real factor prices at time t ,
- B_{it} = the real value of net debt outstanding for firm i at time t ,
- i_t = the nominal interest rate paid on corporate bonds at time t ,

π_t^e = the expected inflation rate at time t ,
 p_{it} = the effective real price of capital goods at time t ,¹¹ and
 τ = the corporate income tax rate.

$F(K_{i,t-1}, N_{it})$ is the firm's real revenue function, which I assume to be concave. It embodies the firm's production function as well as the demand curve it faces. It is important to note that production capabilities depend on the previous period's capital stock. This specification implies that capital goods purchased today are not ready for use until tomorrow.¹² The function $\psi(I_{it}, K_{i,t-1})$ represents the real cost of adjusting the capital stock. I assume increasing, convex adjustment costs; that is, the faster the rate of gross investment, the greater the productivity lost to devoting resources to the installation of new capital goods. In addition, the firm will face positive costs for disinvestment. This assumption captures not only the costs of "unbolting" machines from the floor, but the discount at which a firm must usually sell used capital goods. $\psi(I_{it}, K_{i,t-1})$ and $\psi_I(I_{it}, K_{i,t-1})$ are decreasing in the size of the capital stock. The assumption of economies of scale in installing capital implies that the larger the size of the firm, the less any given size investment project will displace resources from their usual activities, both on average and at the margin.

The third constraint restricts dividends to be non-negative.

$$d_{it} \geq 0. \quad (5)$$

Clearly, if borrowing constraints are to matter in this model, outside equity funding must be limited in some manner. Here, absent taxes, the nonnegativity constraint has the same effect as a restriction on new share issues, since for small increments in outside equity funding, both have the same effect on current stockholders. As in the case of a restriction on debt issuance, this constraint can be loosely interpreted as a premium on outside equity finance.

The fourth constraint is a transversality condition which prevents the firm from borrowing an infinite amount to pay out as dividends:

$$\lim_{T \rightarrow \infty} \left[\prod_{j=t}^{T-1} \beta_{it} \right] B_{iT} = 0, \forall t. \quad (6)$$

Let λ_{it} be the series of Lagrange multipliers associated with the constraint (5). Substituting (4) into (2) for d_{it} , and using (3) to eliminate I_{it} from the problem, the first order conditions of the firm's maximization problem for K_{it}

¹¹ In order to simplify my notation, I allow this price to account for the investment tax credit and the present value of future depreciation deductions stemming from today's investment. This simplification does not alter the results. See Poterba and Summers (1983).

¹² This assumption is a modification of the "time to build" assumption of Kydland and Prescott (1982). It restricts installation time to be one period. See Holtz-Eakin and Rosen (1988) for a similar treatment.

and B_{it} can be calculated as:

$$\begin{aligned} \beta_{it} E_t \left[\left(\frac{1 + \lambda_{i,t+1}}{1 + \lambda_{it}} \right) \left(F_K(K_{it}, N_{i,t+1}) - \psi_K(I_{i,t+1}, K_{it}) \right. \right. \\ \left. \left. + (1 - \delta) \left(\psi_I(I_{i,t+1}, K_{it}) + \frac{P_{i,t+1}}{(1 - \tau)} \right) \right) \right] \\ = \psi_I(I_{it}, K_{i,t-1}) + \frac{P_{it}}{(1 - \tau)}; \end{aligned} \quad (7)$$

$$(1 + \lambda_{it}) - \beta_{it}(1 + (1 - \tau)i_t - \pi_t^e)E_t(1 + \lambda_{i,t+1}) = 0. \quad (8)$$

The right-hand side of equation (7) shows the marginal installation and tax-adjusted purchasing costs of investing today. The left-hand side represents the costs of postponing investment until tomorrow, which consist first of the two components of the marginal product of capital—the foregone marginal change in production and the marginal change in installation costs due to a change in the capital stock. The costs of waiting also include the expected discounted value of the marginal purchasing and installation costs of investing tomorrow. Note that the opportunity cost of investing in the future is weighted by the relative shadow value of tomorrow's dividends versus today's. This valuation effect can be seen by observing that λ_{it} is the value to the firm of being able to obtain equity finance by paying negative dividends. Along the optimal capital accumulation path, the firm must be indifferent between investing today and transferring those resources to tomorrow. Therefore, the costs of these two choices must be equal.

The first order condition for borrowing, equation (8), has a strong analogy in the consumption literature. It says that firms equate the appropriately discounted marginal value of payments to shareholders over time, much in the way that utility maximizing consumers equate the discounted marginal utility of consumption in different periods. Under the assumptions of risk neutrality and perfect capital markets, the after-tax return on debt must equal the required return on equity. Applying this condition to (8) implies further that the firm equates the expected marginal utility of dividends over time. Finally, note that this condition implies an indeterminate capital structure—a result in accord with the underlying assumptions of the neoclassical model.

B. The Model with Borrowing Constraints

The firm now faces an additional constraint in its maximization problem:

$$B_{it} \leq B_{it}^*, \quad (9)$$

where B_{it}^* is the maximum amount of outstanding debt set for firm i at time t . I assume that the firm takes B_{it}^* as given, and that the lending sector determines its level each period according to an assessment of the firm's ability to repay. It is important to note that this series of exogenous constraints implies that the firm cannot affect its credit limit. One interpretation

of this setting is that the major components of a firm's credit-worthiness are either fixed or change slowly over time. For example, such characteristics as the firm's industry or size are fixed in the short run. In addition, other indicators of financial standing such as net stocks of financial assets may take quite some time to build up.

Let the multiplier associated with constraint (9) be γ_{it} . Now, the first order condition (8) can be rewritten as:

$$(1 + \lambda_{it}) - \beta_{it}(1 + (1 - \tau)i_t - \pi_t^e)E_t(1 + \lambda_{i,t+1}) - \gamma_{it} = 0. \quad (10)$$

Here, a wedge has been introduced between the shadow value of today's residual profits and tomorrow's. If the non-negativity constraint on dividends is not binding today, but is expected to bind tomorrow, the firm can save, thereby transferring current resources to the next period, where they are more needed. In this case the debt constraint will not bind and the firm will behave as a standard optimizing model would predict. If, on the other hand, the shadow value of dividends is higher today than it is expected to be tomorrow *and* the firm has hit its debt capacity, it will not be able to borrow in order to maximize its value. Therefore, the term γ_{it} corresponds to increase in the present value of the firm if the debt constraint were to be relaxed by one unit.

To understand the effect of the borrowing constraint on the allocation of investment, substitute (10) into (7). Noting, once again, that the required return on equity equals the after-tax return on debt, the Euler equation (7) then becomes

$$\begin{aligned} & \frac{\beta_{it}}{1 + \gamma_{it} + E_t \lambda_{i,t+1}} E_t \left[(1 + \lambda_{i,t+1}) \left(F_K(K_{it}, N_{i,t+1}) \right. \right. \\ & \quad \left. \left. - \psi_K(I_{i,t+1}, K_{it}) + (1 - \delta) \left(\psi_I(I_{i,t+1}, K_{it}) + \frac{P_{i,t+1}}{(1 - \tau)} \right) \right) \right] \\ & = \psi_I(I_{it}, K_{i,t-1}) + \frac{P_{it}}{(1 - \tau)}. \end{aligned} \quad (11)$$

Compared to an unconstrained firm, a firm facing a binding liquidity constraint has a higher value of γ_{it} and hence incurs a higher marginal opportunity cost of investment today versus delaying it until tomorrow; that is, it behaves as if it has a higher discount rate, since, as discussed above, the value of proceeds from an extra unit of investment are forced to be higher today than tomorrow in the face of a binding constraint. Equation (11) also suggests that, all else equal, firms will intertemporally substitute investment tomorrow for investment today.

III. Econometric Specification and Tests

I test the hypothesis that frictions in debt markets affect firms' investment decisions in two ways, both of which are based directly on the Euler equations (7) and (11). As mentioned above, the major advantage of this approach

is that it allows an examination of the effects of debt limits on the intertemporal allocation of investment, while avoiding the serious measurement problems in constructing an explicit investment demand equation. The first test relies on dividing the sample into groups based on measures of collateral or credit worthiness and then on estimating (7) for the entire sample and for each of the subsamples, under the hypothesis of no constraints on external finance.¹³ The second test is based on estimating a version of (7) that is augmented to incorporate the effects of liquidity constraints. I then examine the significance of these effects across the different subsamples.

A. Specification and Estimation

In order to implement the Euler equation tests, it is necessary to parameterize the model of the previous section. First, I consider a proxy for the marginal product of capital. Under perfect competition and constant returns to scale, the marginal product of capital is simply equal to the average product, measured as the difference between output and real variable factor costs, each in turn measured as a fraction of the capital stock. Unfortunately, if the firm does not have constant returns technology or if it has market power, measurement error will be present. If the firm's production function is homogeneous of degree $\eta > 1$, then the proposed measure will understate the actual value by the amount $(\eta - 1)(Y_{it}/K_{i,t-1})$, where Y_{it} is output. However, if the firm has market power, then, strategic considerations notwithstanding, profit maximization implies that the above measure of the marginal product of capital must be modified by scaling the variable factor costs upward by the term $\mu \equiv (1 - 1/\epsilon_D)^{-1}$, where ϵ_D is the absolute value of the elasticity of the firm's demand curve. Since firms with monopoly power operate on the elastic portion of their demand curves, the above expression should be greater than one. In this case the proposed measure will overstate the true value. Given these considerations, I use the following measure of the marginal product of capital.

$$F_K(K_{i,t-1}, N_{it}) = (\eta Y_{it} - \mu C_{it})/K_{i,t-1}, \quad (12)$$

where C_{it} is variable costs. Here, η and μ are treated as parameters to be estimated.¹⁴

Second, following a number of authors, I assume that the firm faces quadratic adjustment costs.¹⁵ More specifically,

$$\psi(I_{it}, K_{i,t-1}) = \frac{\alpha}{2} \left(\frac{I_{it}}{K_{i,t-1}} - v \right)^2 K_{i,t-1}, \quad (13)$$

where v can be interpreted as a "normal" rate of investment.

¹³ The use of this technique follows Fazzari et al. (1988a, 1988b), as well as a number of studies in the consumption literature, such as Bernanke (1984), Hayashi (1985), and Zeldes (1989).

¹⁴ Gilchrist (1990) provides evidence that a specification that allows for market power better characterizes the data.

¹⁵ See Summers (1981), Poterba and Summers (1983), and Chirinko (1987), for example.

Differentiating (13) with respect to I_{it} and K_{it} , inserting the result into (7), substituting (12) into (7), and rearranging yields:

$$\begin{aligned} & \left(\frac{1 - \Lambda_{it}}{1 + (1 - \tau)\dot{i}_t - \pi_t^e} \right) \left[\frac{\eta Y_{i,t+1} - \mu C_{i,t+1}}{K_{it}} \right] \\ & + \frac{\alpha}{2} \left(\frac{1 - \Lambda_{it}}{1 + (1 - \tau)\dot{i}_t - \pi_t^e} \right) \left[\left(\frac{I_{i,t+1}}{K_{it}} \right)^2 - v^2 \right] \\ & + \alpha(1 - \delta) \left(\frac{1 - \Lambda_{it}}{1 + (1 - \tau)\dot{i}_t - \pi_t^e} \right) \frac{I_{i,t+1}}{K_{it}} \\ & + (1 - \delta) \left(\frac{1 - \Lambda_{it}}{1 + (1 - \tau)\dot{i}_t - \pi_t^e} \right) \frac{P_{i,t+1}}{(1 - \tau)} \\ & - \alpha \frac{I_{it}}{K_{i,t-1}} - \frac{P_{it}}{(1 - \tau)} + f_i + s_t = e_{i,t+1} \end{aligned} \quad (14)$$

Here I have re-normalized the relative shadow value of dividends by defining the term $\Lambda_{it} \equiv 1 - (1 + \lambda_{i,t+1})/(1 + \lambda_{it})$. In the absence of any constraints on outside finance, this variable should equal zero. I have also added a firm fixed effect, f_i , and a fixed time effect s_t . Finally, I have replaced the expectation operator with a white noise expectational error, $e_{i,t+1}$, which is uncorrelated with any information known at time t .

One final requirement for estimating (14) is a specification for the term Λ_{it} . Under the hypothesis of perfect capital markets, both the constraints on outside debt and equity finance are redundant; and, therefore, this term will be identically equal to zero. However, if the debt constraint is binding, equation (10) indicates that it will be a function of the Lagrange multiplier on the debt constraint, γ_{it} . The degree to which the debt constraint binds depends on the firm's desired level of borrowing relative to its exogenous debt limit, B_{it}^* . Since equation (10) implies that *ceteris paribus* a change in γ_{it} will affect Λ_{it} , the latter will be a complicated function of the determinants of the demand for borrowing as well as of the debt limit. This approach implicitly assumes that firms that face imperfections in the debt market also face imperfections in the equity market, so that the alternative hypothesis is that both markets are shut down.¹⁶ Since the first order conditions do not provide an analytical solution for Λ_{it} , I parameterize it as a function of contemporaneous variables that indicate the probability of firm financial distress and then insert the resulting expression into (14).¹⁷ Finally, I use the estimated coefficients of the parameterization to simulate the divergence of the individual firm's discount rate from the after-tax corporate bond rate.

¹⁶ See Myers and Majluf (1984) for a theoretical discussion of why this might be the case. Also, as noted in the introduction, firms' use of outside equity markets is small as compared to their use of outside debt markets.

¹⁷ See MaCurdy (1981), which uses the same approach to estimate the Lagrange multiplier on the consumer's budget constraint.

I use a quadratic approximation for Λ_{it} , though other nonlinear specifications yield qualitatively similar results. The approximation will be increasing and convex in its arguments for positive parameter values. One alternative estimation strategy is to restrict the parameters to be positive. However, this constraint does not bind for the equations here. The function takes the following form:

$$\Lambda_{it} = c(DAR_{it}, COV_{it}) \approx c_0 + c_1 DAR_{it} + c_2 DAR_{it}^2 + c_3 COV_{it} + c_4 COV_{it}^2 \quad (15)$$

Here, DAR_{it} is the ratio of the market value of the firm's debt to the market value of its total assets. This variable can be interpreted, first, as a measure of a firm's lack of collateral, which should lead to a lower level of B_{it}^* . It can also be interpreted as a measure of the current demand for borrowing *relative* to the firm's debt capacity, whose proxy here is the market value of the firm. I also include in the expression for the Lagrange multiplier a flow variable, COV_{it} , which is the ratio of the firm's interest expense to the sum of interest expense plus cash flow. This variable, which I refer to as the interest coverage ratio, indicates the likelihood of firm financial distress, relative to its fundamental health or need to borrow. It captures the idea that if a firm can generate sufficient internal funds, it will not have a great need to borrow and will not be likely to run up against its debt limit.¹⁸

As discussed in Gilchrist (1990) and Himmelberg (1990), adding new share issues to the model adds the possibility that firms can raise funds on alternative margins with different tax consequences. Because of the difference in the tax treatment of dividends and retained earnings, and because of the dependence of the firm's discount rate on the tax cost of its source of finance, a firm whose dividend policy changes over time will have a variable Λ_{it} , and thus a variable discount rate. However, estimating the model with the tax-adjusted discount rates implied by either the assumption external equity finance or internal finance (as opposed to debt finance) changes the results little. Although this experiment does not address directly the issue of

¹⁸ The question arises of the effects of expected future borrowing constraints. If a firm expects to be constrained in the future, it will cut its investment today for the following reasons. First, a homogenous production function implies that the firm takes the marginal product of capital as an exogenous function of the real wage. The marginal product should therefore be independent of the presence of liquidity constraints. Second, solving equation (10) forward implies that the expectation of a future binding borrowing constraint increases the rate at which the firm discounts the future marginal product of capital. Since the shadow value of the capital stock is simply the present value of the future stream of marginal products of capital, these two factors imply that today's shadow value of capital and today's investment will fall. In addition, the firm will want to smooth its future investment stream in order to minimize its adjustment costs. Since the installation cost function is convex, cost minimization implies that expected future decreases in investment should be spread out over time. See D'Autume and Michel (1985) for a similar result. Because DAR_{it} is measured in terms of market value, it should capitalize the above effects of any expected future constraints. The parameterization of the firm's discount rate should therefore reflect these effects.

firms shifting among financing regimes, it does suggest that such behavior does not undermine the Euler equation tests.

To estimate (14) I use the generalized method of moments (GMM) technique outlined in Hansen and Singleton (1982) and Hansen (1982), where I construct the optimal weighting matrix using the method presented in Newey and West (1987a). Rational expectations imply that the error in (14) should be orthogonal to any additional information known at time t . Therefore, any time t variable that is correlated with the variables in the regression will qualify as a valid instrument. If the error term is not orthogonal to the instruments, the overidentifying restrictions should be rejected.

As described above, when estimating (14), I incorporate an individual firm effect. This effect can be interpreted as accounting for firm characteristics such as industry, as well as the time-invariant components of differences in, for example, product demand, capital intensity, and growth opportunities. The time effects can be interpreted as capturing aggregate business cycle forces. I account for them by including time dummies. Garber and King (1983) note that consistent GMM estimation requires that the instruments used be uncorrelated with unobservable shocks to the objective function, since these shocks may be included in the error term. The use of panel data mitigates this problem, since including individual firm effects accounts for the cross-sectional components of these unobservable shocks, while the time dummies subsume the macroeconomic shocks common to all firms.

Because of the presence of lagged dependent variables, the common practice of eliminating the fixed individual effect by removing the means from the variables in the regression will violate the above orthogonality conditions used to identify the model. Instead, I difference (14) and then use instruments dated at $t - 1$, which will still be orthogonal to the moving average error that the differencing creates. I use the following list of instruments: $(I_{i,t-1}/K_{i,t-2})$, $p_{i,t-1}$, $(Y_{i,t-1}/K_{i,t-2})$, $(C_{i,t-1}/K_{i,t-2})$, $DAR_{i,t-1}$, $COV_{i,t-1}$, $(CF_{i,t-1}/K_{i,t-2})$, $(TAX_{i,t-1}/K_{i,t-2})$, $(IEX_{i,t-1}/K_{i,t-2})$, $(DEPR_{i,t-1}/K_{i,t-2})$, $(\Delta INV_{i,t-1}/K_{i,t-2})$, and $Q_{i,t-1}$. Here, $CF_{i,t-1}$ is real cash flow, $TAX_{i,t-1}$ is real tax payments, $IEX_{i,t-1}$ is real interest expense, $DEPR_{i,t-1}$ is real depreciation deductions, $\Delta INV_{i,t-1}$ is the change in total inventories, and $Q_{i,t-1}$ is Tobin's q . An alternative list of instruments would be the differenced values of the above list. The results do not change significantly in this case, most likely because the $t - 2$ component of the differenced instruments are not highly correlated with the Euler equation variables.

B. Testing

For the first group of tests I estimate the Euler equation (14) for the full sample with $\Lambda_{it} = c(DAR_{it}, COV_{it})$ and with Λ_{it} constrained to zero.¹⁹ I then test the joint significance of the c_i 's. Since the model with no debt limit is

¹⁹ Note that the parameter v^2 will be subsumed by the fixed time effects in the model with $\Lambda_{it} = 0$.

nested within the model with a potentially binding liquidity constraint, this test can also be interpreted as a specification test. In order to discern whether differential access to capital markets affects the investment Euler equation, I split the sample according to whether the firm had received a bond rating from *Moody's* by the time of the first year of the sample period. I then test to see if the effect of the Lagrange multiplier is significantly different between the two subsamples. Use of the presample existence of a bond rating avoids violating the orthogonality conditions used to identify the model.

A simple one- to three-letter bond rating contains a great deal of information. Not only does it on one level give a potential investor a good idea of the risk of his or her investment, but it shows that the firm has undergone careful scrutiny regarding its financial health and its future growth opportunities. In addition, as demonstrated by Diamond (1989) in a multiperiod contracting model with moral hazard, firms must generally undergo the monitoring of a financial intermediary before being able to use directly placed debt. The bond rating can thus be seen as a sort of summary statistic of all of this information, and any firm having one will be unlikely to face the same magnitude of informational asymmetries as a firm that does not.²⁰

For the second set of tests I divide the sample of firms twice into three sets of observations based on each of the two indicators of financial distress above. In each classification scheme the first group consists of those firms not likely to face a binding credit constraint. The next two have increasing values of the indicator variable used. Since each of these measures is flawed, and since the consistency of these tests requires that no observation in the first group be constrained, I include in the first group the bottom third of the firms in each categorization scheme. The remaining firms in the sample are split evenly between the two remaining groups. In addition, consistency requires that the variables used to divide the sample not be correlated with the expectational error in the Euler equation. I consequently divide the sample on the basis of the average presample values of each of the financial variables.

This experiment follows Zeldes (1989) by testing the implication that the Euler equation (14) without the Lagrange multiplier, Λ_{it} , should be satisfied for the unconstrained group but not for the others. I also extend this analysis by comparing the strength of the effects of the financial variables between the most and least constrained groups. Under the null hypothesis that no group faces a binding constraint, the overidentifying restrictions should not be rejected; and the parameter estimates should be similar for all groups. Under the alternative hypothesis, Λ_{it} should be positive for all groups but the first, since presumably firms can be constrained from borrowing but not from investing excess funds in financial assets. If Λ_{it} is set equal to zero, the

²⁰ One issue here is whether a firm issuing junk bonds can be grouped together with a firm issuing investment grade bonds. To see if my original classification scheme is valid, I alternatively split the sample according to whether the firm was issuing investment-grade bonds in the year before the first year of the sample period. The qualitative content of the empirical results does not change significantly.

measured error for the constrained groups will contain a non-zero component equal to:

$$\begin{aligned}
 -\Lambda_{it} & \left\{ \left(\frac{1}{1 + (1 - \tau)i_t - \pi_t^e} \right) \left[\frac{\eta Y_{i,t+1} - \mu C_{i,t+1}}{K_{it}} \right] \right. \\
 & + \left(\frac{\alpha/2}{1 + (1 - \tau)i_t - \pi_t^e} \right) \left[\left(\frac{I_{i,t+1}}{K_{it}} \right)^2 - v^2 \right] \\
 & + \left(\frac{\alpha(1 - \delta)}{1 + (1 - \tau)i_t - \pi_t^e} \right) \frac{I_{i,t+1}}{K_{it}} \\
 & \left. + \left(\frac{1 - \delta}{1 + (1 - \tau)i_t - \pi_t^e} \right) \frac{p_{i,t+1}}{(1 - \tau)} \right\}
 \end{aligned}$$

Since the instruments are correlated with the variables in the regression, this expression will be correlated with the instruments. Therefore, its presence in the error term should lead to a rejection of the overidentifying restrictions, should render the parameter estimates for the last two groups inconsistent, and should increase their standard errors.

IV. Data

Most of the data are taken from the combined (primary, supplementary, and tertiary) annual and over-the-counter (OTC) COMPUSTAT industrial files. The firms in the combined annual file are all listed on either the NYSE or the AMEX and are generally quite large. By contrast, the OTC file contains a number of smaller firms whose stock is less actively traded. Such diversity is important to this study, since it concentrates on potential cross-sectional differences in investment patterns.

I select a sample of firms from these files as follows. First, in order to maximize the total number of observations, I use a sample period which runs from 1972 to 1986. Note here that the construction of the change in inventories and the use of lagged instruments implies that the sample period actually used for estimation runs from 1975 to 1986. Second, I consider only firms in the manufacturing sector (with SIC codes between 2000 and 3999).²¹ The total number of manufacturing firms on the combined annual tape is 1024, and on the OTC tape it is 338. I then delete any firm that has missing or inconsistent data or that has been involved in a merger accounting for

²¹ The investment behavior in other sectors may differ substantially from the stylized model presented in Section II. For instance, government regulation influences the public utilities, transportation, and farming industries; and the financial service industries often use different accounting procedures.

more than 15% of its assets.²² This last criterion is necessary for obtaining measures of the required variables that are consistent with one another over time. The sample thus obtained contains 325 firms—286 from the combined annual file and 39 from the OTC file.

Because the sample selection procedure cuts out such a large percentage of the available firms, I investigate the differences between the firms in and out of the sample. The average capital stock of an in-sample firm is 761.11 million 1982 dollars, while the corresponding figure for the out-of-sample firms is 478.17 million 1982 dollars. The mean in-sample debt to assets ratio is 0.339, compared to a significantly different mean out-of-sample figure of 0.385. The out-of-sample firms also have a higher mean coverage ratio, though the difference is not significant. These figures indicate that the firms discarded from the sample are smaller and more highly levered than those retained. The discarded firms may therefore be more likely to face financing constraints. If the effects of such constraints appear in the sample chosen, they may be even more evident in the firms left out.

The primary data requirements for estimating and testing the model of the previous section are firm-specific time-series on output, costs, investment, the tax-adjusted price of capital goods, the interest coverage ratio, and the market debt to assets ratio, as well as all of the other instruments. The explanations of the formulas used for the calculations of these variables are left to the Appendix.

V. Results

Table I provides summary statistics for the full sample and for the subsamples with and without bond ratings. This division of the sample is essentially along the lines of firm size. The median value of the capital stock for the firms that have bond ratings is 17 times as large as the median value for those that do not. The mean and median values of the debt assets ratio and the interest coverage ratio are higher for the firms without bond ratings, as are the rates of investment, sales growth, and cash flow. However, the differences are not significantly different between the two samples. The one important difference between the two groups lies in their debt growth, which is negative for the firms without bond ratings and positive for the firms with bond ratings.

Table II shows similar statistics for the observations in each group as classified by the presample debt to assets ratio. The observations in group 3, those hypothesized to face binding borrowing constraints, have an average value of DAR_{it} of 0.473 and an average value of COV_{it} of 0.481. This group also contains the smallest firms: the median market value of debt plus equity is 79.89 million 1982 dollars, while the replacement value of the capital stock is 34.34 million. These firms also have the lowest ratios of investment to the

²² Since the reporting of acquisitions is incomplete on the COMPUSTAT tape, I double-checked the history of each firm in *Moody's Industrial Manual* for the presence of any significant merger activity.

Table I
**Summary Statistics: Sample of 325 U.S. Manufacturing Firms,
 1972–1986 (Sample Split by the Existence of a Bond Rating)**

Calculations are based on a sample of firms from the COMPUSTAT database. The sample split is based on the pre-sample existence of a bond rating. Capital stock and market value figures are in millions of 1982 dollars. Investment and cash flow are expressed as a fraction of the capital stock. The interest coverage ratio is defined as the ratio of interest expense to the sum of interest expense and cash flow.

	Group of Firms		
	Full Sample	Firms with Bond Ratings	Firms without Bond Ratings
Number of firms	325	119	206
Capital stock			
Mean	761.11	1775.45	234.35
Median	51.53	441.70	26.45
Market value of assets			
Mean	1116.21	2585.97	352.95
Median	137.25	1028.66	69.06
Investment			
Mean	0.188	0.183	0.190
Median	0.167	0.167	0.168
Cash flow			
Mean	0.310	0.283	0.324
Median	0.279	0.257	0.294
Sales growth			
Mean	0.074	0.074	0.074
Median	0.094	0.091	0.097
Outstanding debt growth			
Mean	0.032	0.114	−0.011
Median	0.006	0.013	−0.018
Debt to assets ratio			
Mean	0.339	0.320	0.350
Median	0.303	0.282	0.318
Interest coverage ratio			
Mean	0.311	0.258	0.338
Median	0.164	0.157	0.170

capital stock and of cash flow to the capital stock. For the progressively less constrained groups, the rates of investment and cash flow increase, while the interest coverage ratio decreases. However, neither the market value of total assets nor the capital stock increases monotonically, group 2 having the highest median and average values. Nonetheless, group 1 firms are larger than those in group 3. I interpret this trend to indicate that firm size is an important—but not the dominant—factor in determining access to financial markets.²³ Sales growth remains fairly constant across all three groups,

²³ This finding is not entirely in accord with those in Fazzari et al. (1988a, 1988b) and Hoshi et al. (1990, 1991). In order to verify that my classification schemes do not simply pick up a size effect, I also divide the sample into categories based on the size of the capital stock and on the market value of the firm. The standard neoclassical Euler equation is rejected for both large and small firms, indicating that each group contains some constrained firms.

Table II
Summary Statistics: Sample of 325 U.S. Manufacturing Firms,
1972–1986 (Sample Split by the Debt to Assets Ratio)

Calculations are based on a sample of firms from the COMPUSTAT database. The sample is split on the basis of the pre-sample level of the debt to assets ratio. Group 1 firms have the lowest debt to assets ratios and Group 3 firms the highest. Capital stock and market value figures are in millions of 1982 dollars. Investment and cash flow are expressed as a fraction of the capital stock. The interest coverage ratio is defined as the ratio of interest expense to the sum of interest expense and cash flow.

	Group of Firms		
	Group 1	Group 2	Group 3
Number of firms	109	108	108
Capital stock			
Mean	595.19	1144.78	548.42
Median	68.10	78.39	34.34
Market value of assets			
Mean	1356.96	1385.77	612.47
Median	231.42	175.23	79.89
Investment			
Mean	0.212	0.186	0.164
Median	0.187	0.170	0.143
Cash flow			
Mean	0.387	0.294	0.250
Median	0.348	0.266	0.229
Sales growth			
Mean	0.094	0.076	0.052
Median	0.106	0.093	0.082
Outstanding debt growth			
Mean	0.086	0.062	−0.051
Median	0.041	0.036	−0.102
Debt to assets ratio			
Mean	0.211	0.333	0.473
Median	0.171	0.306	0.472
Interest coverage ratio			
Mean	0.171	0.278	0.481
Median	0.115	0.161	0.233

indicating that the firms have not been effectively sorted by this measure of profitability. The growth rate of the stock of outstanding debt declines sharply, moving from group 1 to group 3, which suggests loosely that the sample-splitting variable is a reasonable measure of the extent to which a firm may be constrained from issuing debt. Table III provides the same statistics for the observations grouped by the coverage ratio. The general trends are similar to those found in Table II.

Tables IV–VI show the results for estimating the Euler equation (14) for each of the three samples with and without the expression (15) substituted in for Λ_{it} . The first column of each table shows that the overidentifying restrictions can be rejected strongly when Λ_{it} is constrained to be zero. With a

Table III

**Summary Statistics: Sample of 325 U.S. Manufacturing Firms,
1972–1986 (Sample Split by the Interest Coverage Ratio)**

Calculations are based on a sample of firms from the COMPUSTAT database. The sample is split on the basis of the pre-sample level of the interest coverage ratio. Group 1 firms have the lowest interest coverage ratios and Group 3 firms the highest. Capital stock and market value figures are in millions of 1982 dollars. Investment and cash flow are expressed as a fraction of the capital stock. The interest coverage ratio is defined as the ratio of interest expense to the sum of interest expense and cash flow.

	Group of Firms		
	Group 1	Group 2	Group 3
Number of firms	109	108	108
Capital stock			
Mean	1035.80	866.01	387.02
Median	51.44	91.84	37.65
Market value of assets			
Mean	1468.73	1242.67	644.22
Median	161.17	202.78	90.44
Investment			
Mean	0.200	0.187	0.175
Median	0.173	0.174	0.152
Cash flow			
Mean	0.371	0.291	0.268
Median	0.333	0.272	0.240
Sales growth			
Mean	0.084	0.078	0.061
Median	0.102	0.095	0.085
Outstanding debt growth			
Mean	0.092	0.039	−0.035
Median	0.068	0.022	−0.014
Debt to assets ratio			
Mean	0.230	0.324	0.461
Median	0.187	0.297	0.457
Interest coverage ratio			
Mean	0.217	0.224	0.489
Median	0.109	0.156	0.244

probability value of 1.66×10^{-5} , Table VI shows that the χ^2 statistic for the test of the overidentifying restrictions is largest for the group of firms without bond ratings, while Table V shows that it is smallest for the group of firms with bond ratings. In contrast, the second through fourth columns of each table show that including a parameterization of Λ_{it} in the Euler equation greatly improves its fit. Here, the second column shows the specification of Λ_{it} that includes both DAR_{it} and COV_{it} . The overidentifying restrictions cannot be rejected at the 10% level for either the full sample or for the two subsamples. For all three samples, the coefficients on the terms explaining Λ_{it} are all of the right sign and in general have low standard errors. For each sample, a test of the exclusion restrictions on the financial variables, con-

Table IV
GMM Estimates of the Augmented Investment Euler Equation:
Full Sample

The sample consists of 325 U.S. manufacturing firms from the COMPUSTAT database from 1975 to 1986. The Euler equation takes the following form:

$$\left(\frac{1 - \Lambda_{it}}{1 + (1 - \tau) i_t - \pi_t^e} \right) \left[\left(\frac{\eta Y_{i,t+1} - \mu C_{i,t+1}}{K_{it}} \right) + \frac{\alpha}{2} \left[\left(\frac{I_{i,t+1}}{K_{it}} \right)^2 - v^2 \right] \right. \\ \left. + \alpha(1 - \delta) \frac{I_{i,t+1}}{K_{it}} + (1 - \delta) \frac{p_{i,t+1}}{(1 - \tau)} \right] - \alpha \frac{I_{it}}{K_{i,t-1}} - \frac{p_{it}}{(1 - \tau)} + f_i + s_t = e_{i,t+1},$$

where Y_{it} , C_{it} , I_{it} , K_{it} , and p_{it} are the output, variable costs, investment, capital stock, and price of capital goods of firm i at time t . π_t^e is the expected inflation rate at time t , and i_t is the nominal interest rate paid on corporate bonds at time t . δ is the rate of depreciation for firm i . τ is the corporate tax rate. The shadow cost of external finance, Λ_{it} , is parameterized as $c_0 + c_1 DAR_{it} + c_2 DAR_{it}^2 + c_3 COV_{it} + c_4 COV_{it}^2$, where DAR_{it} is the debt to assets ratio and COV_{it} is the interest coverage ratio, which is defined as the ratio of interest expense to the sum of interest expense and cash flow. f_i is a fixed firm effect, which is eliminated by differencing the equation. s_t is a time dummy. Asymptotic standard errors are in parentheses. The standard errors are corrected for the moving average errors induced by differencing using the Newey-West (1987a) procedure.

	$\Lambda_{it} = 0$	$\Lambda_{it} = c(DAR_{it}, COV_{it})$		
α	2.026**	1.135**	0.975**	1.104**
(Adjustment cost parameter)	(1.015)	(0.400)	(0.324)	(0.329)
μ	1.344**	0.994**	1.124**	1.108**
(Mark-up)	(0.214)	(0.112)	(0.257)	(0.136)
η	0.967	0.842	0.883	0.944**
(Returns-to-scale parameter)	(0.618)	(0.504)	(0.601)	(0.307)
v^2	—	0.851	1.449	1.224
(“Normal” rate of investment)	—	(0.774)	(0.912)	(0.851)
c_0 (Constant)	—	0.0022	0.0023	0.0036
		(0.0050)	(0.0047)	(0.0091)
$c_1 (DAR_{it})$	—	0.201**	0.317**	—
		(0.094)	(0.168)	
$c_2 (DAR_{it}^2)$	—	0.0068**	0.018	—
		(0.0022)	(0.011)	
$c_3 (COV_{it})$	—	0.026	—	0.054**
		(0.031)		(0.018)
$c_4 (COV_{it}^2)$	—	0.0081*	—	0.041
		(0.0046)		(0.033)
χ^2 (Overidentifying restrictions)	34.229	4.091	8.447	9.388
Degrees of freedom	9	3	5	5
p-Value	8.14×10^{-5}	0.252	0.133	0.095
χ^2 (Exclusion restrictions on Λ_{it})	—	30.138	25.782	24.841
Degrees of freedom	—	6	4	4
p-Value	—	3.70×10^{-5}	3.50×10^{-5}	5.42×10^{-5}

* Indicates significance at the 5% level.
** Indicates significance at the 1% level.

Table V

GMM Estimates of the Augmented Investment Euler Equation: Sample of Firms with Bond Ratings

The sample consists of 119 U.S. manufacturing firms from the COMPUSTAT database from 1975 to 1986. The Euler equation takes the following form:

$$\left(\frac{1 - \Lambda_{it}}{1 + (1 - \tau)i_t - \pi_t^e} \right) \left[\left(\frac{\eta Y_{i,t+1} - \mu C_{i,t+1}}{K_{it}} \right) + \frac{\alpha}{2} \left[\left(\frac{I_{i,t+1}}{K_{it}} \right)^2 - v^2 \right] \right. \\ \left. + \alpha(1 - \delta) \frac{I_{i,t+1}}{K_{it}} + (1 - \delta) \frac{p_{i,t+1}}{(1 - \tau)} \right] - \alpha \frac{I_{it}}{K_{i,t-1}} - \frac{p_{it}}{(1 - \tau)} + f_i + s_t = e_{i,t+1},$$

where Y_{it} , C_{it} , I_{it} , K_{it} , and p_{it} are the output, variable costs, investment, capital stock, and price of capital goods of firm i at time t . π_t^e is the expected inflation rate at time t , and i_t is the nominal interest rate paid on corporate bonds at time t . δ is the rate of depreciation for firm i . τ is the corporate tax rate. The shadow cost of external finance, Λ_{it} , is parameterized as $c_0 + c_1 DAR_{it} + c_2 DAR_{it}^2 + c_3 COV_{it} + c_4 COV_{it}^2$, where DAR_{it} is the debt to assets ratio and COV_{it} is the interest coverage ratio, which is defined as the ratio of interest expense to the sum of interest expense and cash flow. f_i is a fixed firm effect, which is eliminated by differencing the equation. s_t is a time dummy. Asymptotic standard errors are in parentheses. The standard errors are corrected for the moving average errors induced by differencing using the Newey-West (1987a) procedure.

	$\Lambda_{it} = 0$	$\Lambda_{it} = c(DAR_{it}, COV_{it})$		
α	1.734**	1.998**	0.746**	1.238**
(Adjustment cost parameter)	(0.663)	(0.461)	(0.327)	(0.445)
μ	1.450**	1.100**	1.279**	1.191**
(Mark-up)	(0.137)	(0.084)	(0.314)	(0.107)
η	0.598	0.982	1.224	0.669
(Returns-to-scale parameter)	(0.612)	(0.855)	(0.899)	(0.401)
v^2	—	1.003	0.882*	0.900
(“Normal” rate of investment)	—	(4.948)	(0.513)	(0.871)
c_0 (Constant)	—	0.0007	0.0005	0.0015
		(0.0012)	(0.0021)	(0.0024)
c_1 (DAR_{it})	—	0.124*	0.113	—
		(0.072)	(0.089)	
c_2 (DAR_{it}^2)	—	0.0008	0.0081*	—
		(0.0074)	(0.0050)	
c_3 (COV_{it})	—	0.011*	—	0.061*
		(0.007)		(0.038)
c_4 (COV_{it}^2)	—	0.0064	—	0.0084
		(0.0043)		(0.012)
χ^2 (Overidentifying restrictions)	21.004	4.577	6.080	10.375
Degrees of freedom	9	3	5	5
p -Value	0.013	0.206	0.298	0.065
χ^2 (Exclusion restrictions on Λ_{it})	—	16.427	14.924	10.629
Degrees of freedom	—	6	4	4
p -Value	—	0.012	0.0049	0.031

* Indicates significance at the 5% level.

** Indicates significance at the 1% level.

Table VI

**GMM Estimates of the Augmented Investment Euler Equation:
Sample of Firms without Bond Ratings**

The sample consists of 206 U.S. manufacturing firms from the COMPUSTAT database from 1975 to 1986. The Euler equation takes the following form:

$$\left(\frac{1 - \Lambda_{it}}{1 + (1 - \tau)i_t - \pi_t^e} \right) \left[\left(\frac{\eta Y_{i,t+1} - \mu C_{i,t+1}}{K_{it}} \right) + \frac{\alpha}{2} \left[\left(\frac{I_{i,t+1}}{K_{it}} \right)^2 - v^2 \right] \right. \\ \left. + \alpha(1 - \delta) \frac{I_{i,t+1}}{K_{it}} + (1 - \delta) \frac{p_{i,t+1}}{(1 - \tau)} \right] - \alpha \frac{I_{it}}{K_{i,t-1}} - \frac{p_{it}}{(1 - \tau)} + f_i + s_t = e_{i,t+1},$$

where Y_{it} , C_{it} , I_{it} , K_{it} , and p_{it} are the output, variable costs, investment, capital stock, and price of capital goods of firm i at time t . π_t^e is the expected inflation rate at time t , and i_t is the nominal interest rate paid on corporate bonds at time t . δ is the rate of depreciation for firm i . τ is the corporate tax rate. The shadow cost of external finance, Λ_{it} , is parameterized as $c_0 + c_1 DAR_{it} + c_2 DAR_{it}^2 + c_3 COV_{it} + c_4 COV_{it}^2$, where DAR_{it} is the debt to assets ratio and COV_{it} is the interest coverage ratio, which is defined as the ratio of interest expense to the sum of interest expense and cash flow. f_i is a fixed firm effect, which is eliminated by differencing the equation. s_t is a time dummy. Asymptotic standard errors are in parentheses. The standard errors are corrected for the moving average errors induced by differencing using the Newey-West (1987a) procedure.

	$\Lambda_{it} = 0$	$\Lambda_{it} = c(DAR_{it}, COV_{it})$		
α	0.619**	2.225**	1.156**	1.567**
(Adjustment cost parameter)	(0.094)	(0.674)	(0.532)	(0.813)
μ	0.014	1.717**	1.082**	1.049**
(Mark-up)	(0.011)	(0.923)	(0.196)	(0.067)
η	0.420	0.831	0.988**	0.515
(Returns-to-scale parameter)	(0.557)	(1.335)	(0.161)	(0.319)
v^2	—	2.620	1.875	0.846
(“Normal” rate of investment)	—	(3.892)	(1.454)	(0.786)
c_0 (Constant)	—	0.0061	0.0020	0.0073*
		(0.0044)	(0.117)	(0.0044)
c_1 (DAR_{it})	—	0.252**	0.442**	—
		(0.097)	(0.172)	
c_2 (DAR_{it}^2)	—	0.0022*	0.013	—
		(0.0013)	(0.094)	
c_3 (COV_{it})	—	0.039**	—	0.055**
		(0.012)		(0.014)
c_4 (COV_{it}^2)	—	0.0136*	—	0.069
		(0.0079)		(0.042)
χ^2 (Overidentifying restrictions)	38.124	6.033	7.394	8.970
Degrees of freedom	9	3	5	5
p -Value	1.66×10^{-5}	0.110	0.193	0.110
χ^2 (Exclusion restrictions on Λ_{it})	—	32.091	30.730	29.154
Degrees of freedom	—	6	4	4
p -Value	—	1.57×10^{-5}	3.48×10^{-6}	7.27×10^{-6}

* Indicates significance at the 5% level.

** Indicates significance at the 1% level.

ducted by forming the difference between the χ^2 statistics of the constrained and unconstrained models, indicates that the coefficients are jointly significant at the 1% level.²⁴ Note that the magnitudes of the coefficients on the financial variables are uniformly larger for the group of firms that do not use the bond market. For example, comparing Tables V and VI shows that the estimated coefficient on DAR_{it} is 0.252 for the sample without bond ratings and 0.124 for the group with bond ratings. In sum, the effects of financial factors appear to matter more for a priori constrained firms.

This contrast also is evident in the third and fourth columns of Tables IV–VI, where the third column omits the interest coverage ratio and the fourth the debt assets ratio. In addition, the evidence in these columns points to a more important role for the debt assets ratio in picking up the effects of finance constraints. The model that incorporates only the interest coverage ratio is rejected for the full sample and the sample with bond ratings, while the model using only the debt assets ratio is not in each case. However, the exclusion restrictions on either financial variable are rejected for all three groups.

For both the constrained and unconstrained sets of results the estimated values of α are reasonable. They are consistent with the results from other studies that estimate investment Euler equations. In addition, they are far lower than the usual excessively large estimates obtained from reduced form regressions of investment on q , which tend to imply capital stock adjustment speeds of approximately twenty years.²⁵ To understand the economic significance of this parameter, consider the following example. Under the assumption that $v = 0$, if a firm has a capital stock of 500 million dollars and invests 50 million dollars, the value of α of 2.026 for the full sample in the first column of Table IV implies that adjustment costs will be 5.07 million, or about 10% of investment expenditures. Lichtenberg (1988) finds, in contrast, that such costs range from 21% to 35% of investment expenditures.

The Euler equation approach also appears to produce reasonable values for the markup, μ . For the full sample and for each of the two subsamples the values of this parameter are all highly significant and near unity, though only in the first column of Table V is this parameter significantly higher than one. The only exception to this general pattern lies in the first column of Table VI, which shows a value of μ of 0.014 in the model with $\Lambda_{it} = 0$ for the sample of firms without bond ratings. This exception conforms with the theory presented above, since this is the group of firms for which the standard neoclassical model is least likely to hold. In contrast to the precision of the estimates for μ and α , the estimates of η and v^2 are generally not significantly different from zero.

Figure 1 provides the distributions of the simulation of the difference

²⁴ See Newey and West (1987b) for a derivation of this test.

²⁵ See Shapiro (1986), Gilchrist (1990), Himmelberg (1990), and Hubbard and Kashyap (1990) for other studies that estimate a similar adjustment cost parameter. See Summers (1981) for adjustment cost parameters obtained from reduced form regressions.

between individual firms' discount rates and the real Baa bond rate for each of the three samples. These simulated premiums are calculated using estimated coefficients of the full specification of Λ_{it} .²⁶ For each sample the median value of the premium falls below 12%, indicating that the model provides reasonable values of the firm discount rate. This figure also demonstrates that each group contains some firms whose discount rates are ex-

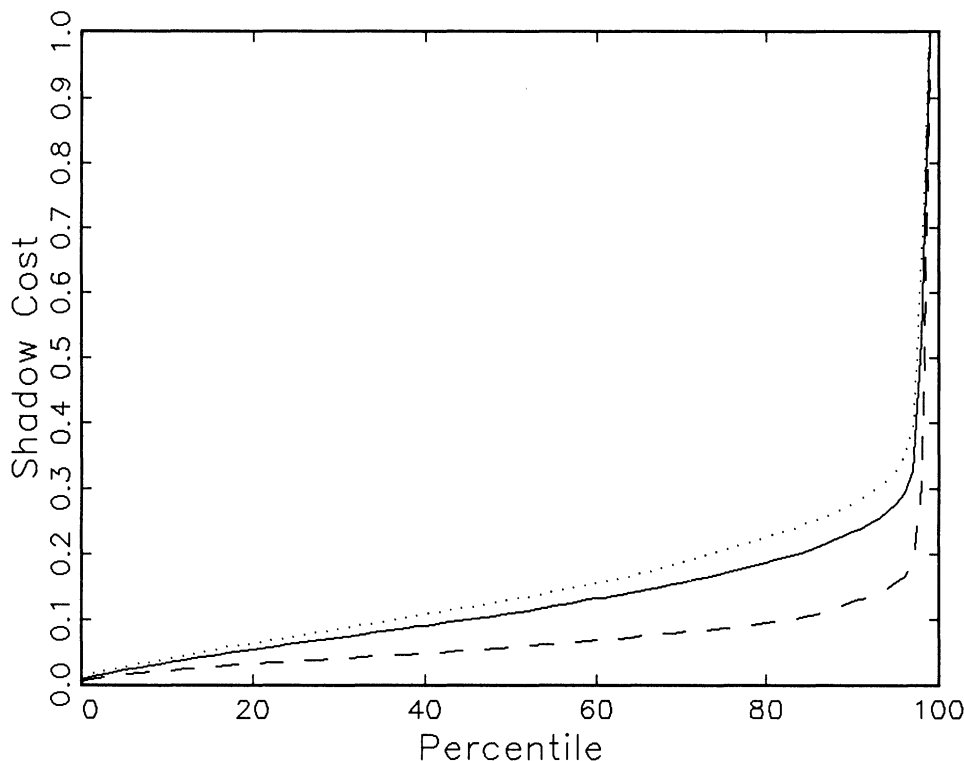


Figure 1. Simulations of the shadow cost of external finance. The sample consists of 325 U.S. manufacturing firms from the COMPUSTAT database from 1975 to 1986. This figure shows the distributions of the simulation of the difference between individual firms' discount rates and the real Baa bond rate in the full sample, and in each of the subsamples divided by the presample existence of a bond rating. The solid line represents the full sample, the dashed line represents the sample of 119 firms with bond ratings, and the dotted line represents the sample of 206 firms without bond ratings. The simulations are calculated using the estimated coefficients from the investment Euler equation, where the shadow cost of outside finance is parameterized as $\Lambda_{it} = c_0 + c_1 DAR_{it} + c_2 DAR_{it}^2 + c_3 COV_{it} + c_4 COV_{it}^2$. DAR_{it} represents the firm's debt to assets ratio, and COV_{it} represents its interest coverage ratio, which is defined as the ratio of interest expense to the sum of interest expense and cash flow.

²⁶ Using a restricted specification does not alter the qualitative character of the simulations, and I therefore omit these results for brevity.

tremely high, approaching 100%. This result suggests that some firms in each sample face severe credit constraints and is consistent with rejection of the overidentifying restrictions of the simple model for all three groups. The most striking feature of this figure is that the firms with bond ratings have lower premiums than the full sample or especially than the firms without bond ratings. This result is consistent with the motivation for splitting the sample by the existence of a bond rating.

An important question arises here as to whether this difference is due to the presence of financial market imperfections or merely to differences in the riskiness of the firms in the different samples. Recall that the model is derived under the assumption of risk neutrality. Dropping this assumption would imply that high-risk firms would have higher discount rates than low-risk firms. In general, the argument can be made that the firms with bond ratings would be less risky than the firms without. Moreover, the proxies for the discount rate, DAR_{it} and COV_{it} , may also be picking up some of this difference in riskiness. However, the risk of any individual firm should be primarily related to the *variability* of its earnings. To the extent that this variance is constant over time, it should be picked up by the fixed effect.

The results of estimating equation (14) with Λ_{it} constrained to zero for each of the three groups classified by the debt assets ratio are reported in Table VII. Recall from the previous section that the presence of this unobserved Lagrange multiplier in the estimated Euler equation should bias the results for the constrained groups of observations. For the high-collateral group 1, the overidentifying restrictions cannot be rejected, the probability value of the χ^2 statistic for testing these restrictions being 0.400. As expected, for the last two groups the overidentifying restrictions are rejected at the 10% level; and the group 3 estimates of α and μ have large standard errors. As Table VIII shows, the results for the sample split by the coverage ratio are similar.

The natural question to ask at this point is whether the model with a variable Λ_{it} fits for the financially healthy firms. If the standard model is indeed appropriate for these firms, the additional parameters introduced with the less restrictive specification should not be significant. Table IX presents the results of this experiment. Here, the exclusion restrictions on the financial variables cannot be rejected for either the low-debt or the low-coverage firms. However, the model that contains both DAR_{it} and COV_{it} is rejected at the 10% level for both groups of firms. I contrast these results with those of estimating the augmented model for the most constrained firms, which are contained in Table X. Here, the exclusion restrictions on the financial variables are all strongly rejected; and the coefficients on these variables are in general higher than those in Table IX, though some exceptions exist. One would expect that for the financially unhealthy firms, the augmented model should fit particularly well. As in the case of the healthy firms, however, the fully augmented model is rejected for both groups, as is the model containing only the interest coverage ratio for the sample of high-debt firms.

Table VII

**GMM Estimates of the Neoclassical Investment Euler Equation:
Sample Split by the Debt to Assets Ratio**

The sample consists of 325 U.S. manufacturing firms from the COMPUSTAT database from 1975 to 1986. The sample is split into three equally sized groups on the basis of the pre-sample level of the debt to assets ratio. Group 1 firms have the lowest debt to assets ratios and Group 3 firms the highest. The Euler equation takes the following form:

$$\left(\frac{1}{1 + (1 - \tau)i_t - \pi_t^e} \right) \left[\left(\frac{\eta Y_{i,t+1} - \mu C_{i,t+1}}{K_{it}} \right) + \frac{\alpha}{2} \left(\frac{I_{i,t+1}}{K_{it}} \right)^2 \right. \\ \left. + \alpha(1 - \delta) \frac{I_{i,t+1}}{K_{it}} + (1 - \delta) \frac{p_{i,t+1}}{(1 - \tau)} \right] - \alpha \frac{I_{it}}{K_{i,t-1}} - \frac{p_{it}}{(1 - \tau)} + f_i + s_t = e_{i,t+1},$$

where Y_{it} , C_{it} , I_{it} , K_{it} , and p_{it} are the output, variable costs, investment, capital stock, and price of capital goods of firm i at time t . π_t^e is the expected inflation rate at time t , and i_t is the nominal interest rate paid on corporate bonds at time t . δ is the rate of depreciation for firm i . τ is the corporate tax rate. f_i is a fixed firm effect, which is eliminated by differencing the equation. s_t is a time dummy. Asymptotic standard errors are in parentheses. The standard errors are corrected for the moving average errors induced by differencing using the Newey-West (1987a) procedure.

	Group of Firms		
	Group 1	Group 2	Group 3
α	2.046**	0.543**	0.712
(Adjustment cost parameter)	(1.056)	(0.256)	(0.594)
μ	1.075**	0.740**	0.908
(Mark-up)	(0.054)	(0.308)	(0.734)
η	0.894	-0.054	0.071
(Returns-to-scale parameter)	(0.789)	(0.083)	(0.135)
χ^2 (Overidentifying restrictions)	9.417	15.560	21.228
Degrees of freedom	9	9	9
p -Value	0.400	0.077	0.012

* Indicates significance at the 5% level.

** Indicates significance at the 1% level.

VI. Concluding Remarks

The poor performance of standard models of business fixed investment is often attributed to the presence of frictions in financial markets. This paper explores the behavior of investment when firms maximize their value subject to borrowing constraints and presents some evidence consistent with the view that information and incentive problems in debt markets affect corporate investment. The evidence suggests that any attempt to understand investment in the aggregate must account for firms' differential access to capital markets—in particular, debt markets. The empirical results presented should, however, be interpreted with some caution. The difficulty in constructing an ideal measure of an indicator of financial distress may undermine the bases

Table VIII

**GMM Estimates of the Neoclassical Investment Euler Equation:
Sample Split by the Interest Coverage Ratio**

The sample consists of 325 U.S. manufacturing firms from the COMPUSTAT database from 1975 to 1986. The sample is split into three equally sized groups on the basis of the pre-sample level of the interest coverage ratio, which is defined as the ratio of interest expense to the sum of interest expense and cash flow. Group 1 firms have the lowest interest coverage ratios and Group 3 firms the highest. The Euler equation takes the following form:

$$\left(\frac{1}{1 + (1 - \tau)i_t - \pi_t^e} \right) \left[\left(\frac{\eta Y_{i,t+1} - \mu C_{i,t+1}}{K_{it}} \right) + \frac{\alpha}{2} \left(\frac{I_{i,t+1}}{K_{it}} \right)^2 \right. \\ \left. + \alpha(1 - \delta) \frac{I_{i,t+1}}{K_{it}} + (1 - \delta) \frac{P_{i,t+1}}{(1 - \tau)} \right] - \alpha \frac{I_{it}}{K_{i,t-1}} - \frac{P_{it}}{(1 - \tau)} + f_i + s_t = e_{i,t+1},$$

where Y_{it} , C_{it} , I_{it} , K_{it} , and p_{it} are the output, variable costs, investment, capital stock, and price of capital goods of firm i at time t . π_t^e is the expected inflation rate at time t , and i_t is the nominal interest rate paid on corporate bonds at time t . δ is the rate of depreciation for firm i . τ is the corporate tax rate. f_i is a fixed firm effect, which is eliminated by differencing the equation. s_t is a time dummy. Asymptotic standard errors are in parentheses. The standard errors are corrected for the moving average errors induced by differencing using the Newey-West (1987a) procedure.

	Group of Firms		
	Group 1	Group 2	Group 3
α	1.774**	0.972*	0.078
(Adjustment cost parameter)	(0.686)	(0.534)	(0.056)
μ	1.011**	0.858**	1.024
(Mark-up)	(0.067)	(0.219)	(0.630)
η	0.834	0.0027	-0.017*
(Returns-to-scale parameter)	(0.652)	(0.011)	(0.0079)
χ^2 (Overidentifying restrictions)	8.452	17.771	29.651
Degrees of freedom	9	9	9
p-Value	0.489	0.038	5.03×10^{-4}

* Indicates significance at the 5% level.

** Indicates significance at the 1% level.

of the tests; that is, the parameterization of the unobserved component of the firm's discount rate as well as the accurate sorting of observations into constrained and unconstrained groups.

Aside from these problems, the evidence suggests that difficulties in obtaining debt finance have an impact on investment. Altering the standard neoclassical model of investment by including the effect of a binding debt constraint allows for the indirect measurement of the individual firm's discount rate, which in turn greatly improves the performance of the Euler equation governing the evolution of investment and the capital stock. Moreover, the effect of the constraint appears to be stronger for firms that do not participate in the corporate bond market.

Table IX
GMM Estimates of the Augmented Investment Euler Equation:
Samples of Financially Healthy Firms

The two samples consist of 109 U.S. manufacturing firms from the COMPUSTAT database from 1975 to 1986. The first includes firms with low debt to assets ratios; and the second consists of firms with low interest coverage ratios, which are defined as the ratios of interest expense to the sum of interest expense and cash flow. The Euler equation takes the following form:

$$\left(\frac{1 - \Lambda_{it}}{1 + (1 - \tau)i_t - \pi_t^e} \right) \left[\left(\frac{\eta Y_{i,t+1} - \mu C_{i,t+1}}{K_{it}} \right) + \frac{\alpha}{2} \left[\left(\frac{I_{i,t+1}}{K_{it}} \right)^2 - v^2 \right] \right. \\ \left. + \alpha(1 - \delta) \frac{I_{i,t+1}}{K_{it}} + (1 - \delta) \frac{p_{i,t+1}}{(1 - \tau)} \right] - \alpha \frac{I_{it}}{K_{i,t-1}} - \frac{p_{it}}{(1 - \tau)} + f_i + s_t = e_{i,t+1},$$

where Y_{it} , C_{it} , I_{it} , K_{it} , and p_{it} are the output, variable costs, investment, capital stock, and price of capital goods of firm i at time t . π_t^e is the expected inflation rate at time t , and i_t is the nominal interest rate paid on corporate bonds at time t . δ is the rate of depreciation for firm i . τ is the corporate tax rate. The shadow cost of external finance, Λ_{it} , is parameterized as $c_0 + c_1 DAR_{it} + c_2 DAR_{it}^2 + c_3 COV_{it} + c_4 COV_{it}^2$, where DAR_{it} is the debt to assets ratio and COV_{it} is the interest coverage ratio. f_i is a fixed firm effect, which is eliminated by differencing the equation. s_t is a time dummy. Asymptotic standard errors are in parentheses. The standard errors are corrected for the moving average errors induced by differencing using the Newey-West (1987a) procedure.

	Low-Debt Firms			Low-Coverage Firms		
α	0.956**	1.051**	1.312**	1.742**	1.244*	1.646**
(Adjustment cost parameter)	(0.222)	(0.302)	(0.632)	0.573	(0.691)	(0.872)
μ	1.033**	1.218**	1.322**	1.567**	1.437**	1.438**
(Mark-up)	(0.078)	(0.149)	(0.181)	(0.439)	(0.694)	(0.407)
η	0.998	0.839	0.814	0.643	0.140	0.632
(Returns-to-scale parameter)	(0.712)	(0.710)	(1.132)	(0.520)	(0.710)	(0.694)
v^2	1.172	1.716	0.870	1.490	0.552	1.005
(“Normal” rate of investment)	(0.691)	(1.331)	(0.629)	(1.539)	(0.824)	(0.621)
c_0 (Constant)	0.0009	0.0009	0.0069	0.0099	0.0012	0.0013
	(0.0028)	(0.0016)	(0.0043)	(0.014)	(0.0008)	(0.0218)
c_1 (DAR_{it})	0.100*	0.094	—	0.381	0.102	—
	(0.053)	(0.168)		(0.200)	(0.071)	
c_2 (DAR_{it}^2)	0.0012	0.0073*	—	0.0002	0.0065	—
	(0.0058)	(0.0044)		(0.0054)	(0.0046)	
c_3 (COV_{it})	0.023	—	0.096	0.016*	—	0.055
	(0.038)		(0.088)	(0.0087)		(0.064)
c_4 (COV_{it}^2)	0.0047	—	0.0092	0.0029	—	0.0014
	(0.0041)		(0.013)	(0.0097)		(0.0076)
χ^2 (Overidentifying restrictions)	6.959	6.037	8.719	7.503	7.560	8.137
Degrees of freedom	3	5	5	3	5	5
p -Value	0.073	0.303	0.121	0.057	0.182	0.149
χ^2 (Exclusion restrictions on Λ_{it})	2.458	3.380	0.698	0.949	0.892	0.315
Degrees of freedom	6	4	4	6	4	4
p -Value	0.873	0.496	0.952	0.987	0.926	0.989

* Indicates significance at the 5% level.
** Indicates significance at the 1% level.

Table X

GMM Estimates of the Augmented Investment Euler Equation: Samples of Financially Unhealthy Firms

The two samples consist each of 108 U.S. manufacturing firms from the COMPUSTAT database from 1975 to 1986. The first includes firms with high debt to asset ratios; and the second consists of firms with high interest coverage ratios, which are defined as the ratios of interest expense to the sum of interest expense and cash flow. The Euler equation takes the following form:

$$\left(\frac{1 - \Lambda_{it}}{1 + (1 - \tau)i_t - \pi_t^e} \right) \left[\left(\frac{\eta Y_{i,t+1} - \mu C_{i,t+1}}{K_{it}} \right) + \frac{\alpha}{2} \left[\left(\frac{I_{i,t+1}}{K_{it}} \right)^2 - v^2 \right] \right] + \alpha(1 - \delta) \frac{I_{i,t+1}}{K_{it}} + (1 - \delta) \frac{p_{i,t+1}}{(1 - \tau)} - \alpha \frac{I_{it}}{K_{i,t-1}} - \frac{p_{it}}{(1 - \tau)} + f_i + s_t = e_{i,t+1},$$

where Y_{it} , C_{it} , I_{it} , K_{it} , and p_{it} are the output, variable costs, investment, capital stock, and price of capital goods of firm i at time t . π_t^e is the expected inflation rate at time t , and i_t is the nominal interest rate paid on corporate bonds at time t . δ is the rate of depreciation for firm i . τ is the corporate tax rate. The shadow cost of external finance, Λ_{it} , is parameterized as $c_0 + c_1 DAR_{it} + c_2 DAR_{it}^2 + c_3 COV_{it} + c_4 COV_{it}^2$, where DAR_{it} is the debt to assets ratio and COV_{it} is the interest coverage ratio. f_i is a fixed firm effect, which is eliminated by differencing the equation. s_t is a time dummy. Asymptotic standard errors are in parentheses. The standard errors are corrected for the moving average errors induced by differencing using the Newey-West (1987a) procedure.

	High-Debt Firms			High-Coverage Firms		
α (Adjustment cost parameter)	1.056** (0.511)	1.261** (0.308)	0.526* (0.292)	1.123** (0.490)	1.326** (0.382)	1.017** (0.364)
μ (Mark-up)	1.309** (0.245)	1.108** (0.269)	0.977** (0.150)	0.998** (0.155)	1.113** (0.304)	1.403** (0.024)
η (Returns-to-scale parameter)	1.425* (0.794)	0.905 (0.533)	0.900 (1.112)	0.805 (0.522)	0.862 (0.889)	0.461 (0.411)
v^2 (“Normal” rate of investment)	2.764 (1.926)	1.753 (0.974)	0.832 (0.536)	2.622 (1.916)	0.873 (1.540)	0.662 (0.724)
c_0 (Constant)	0.0089 (0.0062)	0.0009 (0.0043)	0.0031 (0.0029)	0.0091* (0.0051)	0.0052 (0.0031)	0.0045* (0.0026)
c_1 (DAR_{it})	0.241** (0.108)	0.426** (0.096)	—	0.364** (0.147)	0.343** (0.167)	—
c_2 (DAR_{it}^2)	0.0025 (0.049)	0.025 (0.471)	—	0.016** (0.0052)	0.103 (0.068)	—
c_3 (COV_{it})	0.094** (0.049)	—	0.021** (0.0066)	0.055* (0.031)	—	0.060 (0.054)
c_4 (COV_{it}^2)	0.0004 (0.0003)	—	0.081 (0.927)	0.0005 (0.014)	—	0.055 (0.029)
χ^2 (Overidentifying restrictions)	6.958	6.645	9.433	8.997	5.952	8.758
Degrees of freedom	3	5	5	3	5	5
p -Value	0.073	0.248	0.019	0.029	0.311	0.119
χ^2 (Exclusion restrictions on Λ_{it})	14.270	14.583	11.795	20.654	23.699	20.893
Degrees of freedom	6	4	4	6	4	4
p -Value	0.027	0.0056	0.093	0.0021	9.18×10^{-5}	3.33×10^{-4}

* Indicates significance at the 5% level.

** Indicates significance at the 1% level.

The tests based on dividing the sample on the basis of financial health also support this result. The unconstrained Euler equation is violated for those observations likely to face a binding constraint, whereas it cannot be rejected for the groups of *a priori* unconstrained firms. In addition, financial variables appear to be significant for the constrained firms but not for the unconstrained firms. The large size of the firms in the sample as a whole adds credibility to these results, since the majority of manufacturing corporations in the U.S. are smaller than those in the sample, and since such small firms may be even more restricted in their attempts to borrow funds.

In sum, these results add to the mounting evidence concerning the dependence of some firms' investment on liquidity variables. They expand this general conclusion in three important directions. First, firms are separated by their presample access to organized bond markets or their presample financial health instead of, as in Fazzari et al. (1988a, 1988b), by their dividend policy, which is certainly simultaneously determined with their investment decisions. This method of classification is also more valid in the sense that it assumes that firms are constrained more on the margin of debt finance than on that of outside equity finance, which is the basis for separating firms on the basis of their payout ratios. Second, this analysis avoids the criticism of the work using cash flow that current cash flow may be picking up expectations of future profits not captured by average q . Finally, using the Euler equation approach emphasizes the effects of liquidity constraints on the firm's discount rate and therefore on its intertemporal allocation of investment.

In addition, the results have some important implications for the current behavior of the corporate sector. First, they support the idea put forth in Bernanke (1983) and Bernanke and Gertler (1989, 1990) that shocks to financial markets or to a firm's net worth may affect the level of real output. An economy-wide deterioration of firms' balance sheets should show up as a drop in borrowing, which should subsequently spill over into substitution of investment today for investment in the future. Such behavior on the part of firms might be an important catalyst in an economic downturn. Evidence contained in Bernanke and Campbell (1988) and Bernanke, Campbell, and Whited (1990) on the build-up of corporate debt among U.S. firms in the late 1980's points to the relevance of this theory to the U.S. economy.

One important implication of the model not explored here is the time-series interaction between a firm's balance sheet position and its investment expenditures. The adjustment cost function implies that a firm in need of liquid funds cannot convert capital goods into cash without suffering a loss. This sort of irreversibility in turn implies that a financially troubled firm may cut investment in order to build up its asset base.²⁷ Strictly speaking, the model presented here has little to say about such phenomena, since it does not allow

²⁷ See the discussion in Eckstein and Sinai (1986) concerning the co-movements of firm balance sheet positions and investment expenditure over the business cycle.

collateral to be a choice variable. A more rigorous study of this topic is left to further research.

Data Appendix

This appendix is organized as follows. First I describe in general terms the actual variables and instruments used in the regressions. I then set out the details of the calculations of the underlying variables used to construct the regression variables. In what follows I have dropped the i subscript for convenience.

Investment: I_t is reported spending on plant, property, and equipment. It does not include spending on acquisitions.

Output: Y_t is sales plus the change in finished goods inventories. The change in finished goods inventories is taken directly from the COMPUSTAT tape, when available. If the number is not reported, I calculate it as 0.23 times the value of total inventories. The figure 0.23 is the average ratio of finished goods inventories to total inventories among the 46% of the firms in the sample that report this data.

Costs: C_t consists of costs of goods sold plus general, selling, and administrative expenses.

Relative Price of Capital Goods: The tax-adjusted price of capital goods can be expressed as follows:

$$p_t = \frac{(1 - u_t - \tau z_t)P_t^k}{PPI_t}, \quad (\text{A1})$$

where PPI_t is the 2-digit industry-specific producer price index at time t and P_t^k is the deflator for non-residential investment. Both are taken from the 1987 *Economic Report of the President*. u_t is the rate of the investment tax credit at time t , and z_t is the present value of future depreciation deductions stemming from investment at time t . See Poterba and Summers (1983) for a derivation. I calculate u_t by applying the statutory rate of the investment tax credit to an aggregate measure of the mix of structures and equipment, which comes from the NIPA. I calculate z_t using the formula in Feldstein and Jun (1986):

$$z_t = \frac{\delta}{\delta + \frac{r_t}{1 - c}}, \quad (\text{A2})$$

In this formula $\delta = 2/L$, where L is the estimated average life of capital goods described below. r_t equals the difference between $(1 - r)$ Baa _{t} and a measure of expected inflation from the Livingston Survey of twelve-month inflation expectations. c is the accrual equivalent tax rate on capital gains, which I set equal to 0.05.

Cash Flow: CF_t is calculated as the sum of income and depreciation.

Debt to Assets Ratio: $DAR_t = D_t / (D_t + E_t)$, where D_t is the market value of the firm's debt and E_t is the market value of its equity.

Coverage Ratio: $COV_t = IEX_t / (IEX_t + CF_t)$.

Tobin's q: I calculate Q_t as follows:

$$Q_t = \frac{D_t + E_t - INV_t}{K_{t-1}}. \quad (A3)$$

$D_t + E_t - INV_t$ represents the market value of the capital stock. Here, I have subtracted the replacement value of inventories from the sum of the market values of debt and equity, since inventories are included in the market value of the firm but do not contribute to the market value of the capital stock itself.

Taxes and Depreciation: TAX_t and $DEPR_t$ are taken directly from the COMPUSTAT type.

Replacement Value of Inventories: For firms using the FIFO method, inventories are valued at current cost, and book value equals replacement value. However, for firms using LIFO, inventories are valued at historical cost. To convert book to replacement value, I first assume that the reported value of LIFO inventories is equal to the replacement value for the first year the firm appears on the tape. Following Salinger and Summers (1983), I assume that inventories are rolled over each year and use the following formulas to calculate their replacement value:

$$\begin{aligned} INV_t &= INV_{t-1}(PPI_t/PPI_{t-1}) + INV_t^* - INV_{t-1}^* \text{ if } INV_t^* \geq INV_{t-1}^*; \\ INV_t &= (INV_{t-1} + INV_t^* - INV_{t-1}^*)(PPI_t/PPI_{t-1}) \text{ if } INV_t^* < INV_{t-1}^*. \end{aligned} \quad (A4)$$

Here, INV_t is the replacement value of LIFO inventories at time t and INV_t^* is their reported value.

Replacement Value of the Capital Stock: In order to convert the book value of the gross capital stock into its replacement value, I use the perpetual inventory method described in Salinger and Summers (1983). First, I set the replacement value of the capital stock equal to the book value of gross plant, property, and equipment for the first year the firm appears on the tape. For 67% of the firms, this starting date occurs before 1962, when low inflation would not have caused much of a gap between the replacement value of capital and figures based on historical cost. For new firms that appear on the tape in later years, the book value of the capital stock in the first year is a reasonable approximation for the replacement value. However, for existing firms that appear in later years, this approximation will not be as good. Using the net value of plant, property, and equipment did not alter the empirical results significantly.

Next, I estimate the useful life of capital goods in any year using the formula:

$$L_t = \frac{GK_{t-1} + I_t}{DEPR_t} \quad (A5)$$

Here L_t is the useful life of capital goods at time t and GK_{t-1} is the reported value of gross property, plant, and equipment at time $t - 1$. I then take the average over time of L_t and use this average value, L , in the following formula to define the replacement value of the capital stock:

$$K_t = \left(K_{t-1} \left(\frac{P_t^k}{P_{t-1}^k} \right) + I_t \right) (1 - 2/L) \quad (\text{A6})$$

The second term represents the amount of the capital stock that depreciates each year and is based on the assumption that economic depreciation is double declining balance. See Salinger and Summers (1983) for the other assumptions necessary to use this method of calculation.

Market Value of Equity: E_{it} is calculated as the sum of the market value of preferred stock and the market value of common stock. The latter is calculated simply as the number of common shares outstanding times the end-of-year share price. The market value of preferred stock is its dividend capitalized by Moody's medium-grade dividend yield, under the assumption that dividends are paid forever.

Market Value of Debt: I use the method set forth in Bernanke and Campbell (1988) to convert the book value of debt into the market value. Since COMPUSTAT only provides limited information on the different maturities of debt, it is necessary to construct the maturity distribution of long-term debt from historical information on debt issues. The first step consists of using the method of Brainard, Shoven, and Weiss (1980) to construct the maturity distribution of book debt under the assumption that all long-term debt matures in twenty years. First, each individual firm's maturity distribution is set equal to the aggregate for the first year that the firm appears on the tape. Then, if D_{jt} is debt due in j years at time t , LTD_t is the reported value of long-term debt at time t , and DI_t is the amount of debt issued at time t , the maturity distribution is updated as follows:

$$\begin{aligned} D_{20t} &= DI_t = LTD_t - (LTD_{t-1} - D_{1,t-1}) \\ &\quad \text{if } LTD_t - (LTD_{t-1} - D_{1,t-1}) \geq 0 \\ D_{20t} &= DI_t = 0 \text{ if } LTD_t - (LTD_{t-1} - D_{1,t-1}) < 0 \end{aligned} \quad (\text{A7})$$

and

$$D_{jt} = D_{j+1,t-1}, \quad j = 1, \dots, 19. \quad (\text{A8})$$

If $LTD_t - (LTD_{t-1} - D_{1,t-1}) < 0$, debt retirement is distributed proportionately across the maturity distribution; that is, debt due in one to nineteen years is scaled down by the factor:

$$\frac{LTD_t}{LTD_{t-1} - D_{1,t-1}}.$$

The second step consists of replacing the estimated values of debt due in years one through five with the actual COMPUSTAT numbers and rescaling

the rest of the maturity distribution to be consistent with the total amount of long-term debt.

$$D_{jt}^a = D_{jt}^*, j = 1, \dots, 5;$$

$$D_{jt}^a = D_{jt} \left(1 + \left(\sum_{j=1}^5 (D_{jt} - D_{jt}^*) \right) \div \left(\sum_{j=6}^{20} D_{jt} \right) \right), \quad j = 6, \dots, 20. \quad (\text{A9})$$

Here, D_{jt}^a is the adjusted value of debt due in j years and D_{jt}^* is the reported value of debt due in j years for j equal to one through five.

The final modification adjusts the value of total book debt to make reported interest expense consistent with that implied by assuming that the firm's interest rate on debt issued at time t is the Baa rate at time t . First, the new value of total book value is scaled as follows:

$$NLTD_t = LTD_t \times IEX_t \div \left(\sum_{j=1}^{20} \text{Baa}_{t+j-20} D_{jt}^a \right), \quad (\text{A10})$$

where $NLTD_t$ is the scaled value of long-term debt at time t , Baa_t is the interest rate on grade Baa bonds at time t , and IEX_t is the reported amount of interest expense at time t . The new maturity distribution is then set proportional to the old.

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