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Investment and Research and Development at the Firm Level: Does the Source of Financing Matter?

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Abstract

The elasticity of investment and R&D investment with respect to cash flow is unambiguously positive in a large panel of U.S. manufacturing firms from 1973 to 1987, even with proper controls for permanent differences across firms and for simultaneity. I argue that the evidence favors liquidity constraints rather than just demand effects as the cause of this finding. Other results are that debt is not favored as a form of finance for R&D-intensive firms: leverage ratios and R&D investment are strongly negatively correlated across firms and this is not accounted for by differences in corporate taxation. Finally, the contemporaneous relationship between changes in debt levels and investment which I have previously documented (Hall 1990b and Hall 1991) is one of simultaneity, and apparently transitory, unlike the relationship between cash flow and investment.

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INVESTMENT AND RESEARCH AND DEVELOPMENT AT THE FIRM LEVEL: DOES THE SOURCE OF FINANCING MATTER?

Bronwyn H. Hall

1. Introduction.

In recent work (Hall 1990b and Hall 1991a), I found strong evidence that changes in the financial structure of firms which tilted the balance sheet toward debt were followed immediately by substantial reductions in both investment and R&D in a large panel of U.S. manufacturing firms during the 1980s. In the case of R&D investment, these reductions (in the approximately 250 firms which increased their debt by at least one half the book value of the capital stock during one year) were large enough to account for a reduction in private industrial R&D spending in the United States of 2.5 percent, about one billion 1982 dollars. The numbers for ordinary investment are even larger: the same 250 firms experienced a fall in total investment of about ten billion 1982 dollars, which is approximately five percent of gross investment in the publicly traded manufacturing sector.

Why did this occur? It is not difficult to explain the increase in leverage of U.S. corporations during the 1980s: one only need to point to the tax reform legislation Acts of 1981 and 1986, which have lowered the relative price of debt capital to equity capital by about 50 percent (Poterba, Krugman, and Hatsopolous 1988). But was the associated fall in investment a coincidence, also induced by the high real interest rates which prevailed during the same period, or is there a direct connection between the two phenomena? Increases in leverage and declines in investment could coincide for two reasons, which have slightly different policy implications: on the one hand, the investment being cut may have been excessive, at least from the point of view of the owners (shareholders) of the firm, and the leverage increase (possibly induced by a hostile takeover bid) may be discipline for the managers, forcing them to the external capital markets in order to finance their projects (see Jensen 1986, 1989 for arguments of this kind). On the other hand, investment may also decline because the reduced availability of internal funds for investment has increased the actual cost of capital which these firms are facing, although the foregone projects might have been value-enhancing under the original capital structure.

Both explanations of the relationship between leverage and investment cuts accept as given the idea that forcing firms to external markets for capital will raise the cost of capital to the firm, and that this will lead to declines in investment. The debate is over the value of the foregone investments: first, have the managers or the market been myopic in making the shift to a high leverage-low investment environment? Second, even if the shift is a privately value-maximizing one under the current tax system and macroeconomic environment, should the public be concerned over the loss of some R&D investment because of the positive externality issues cited earlier?

This paper takes one step backwards from this debate and explores more thoroughly the empirical evidence for the premises on which it is based. In particular, I use insights and modeling developments from the modern literature on liquidity constraints and investment (see, for example, Fazzari, Hubbard, and Petersen 1988) to investigate more carefully the behavior of both types of investment at the firm level. I focus on two questions: first, are the declines in investment and R&D following a leverage increase consistent with a cash flow explanation (higher interest expense leaves less room for investment expenditure), and second, is there evidence that R&D and investment are affected differently by the choice of corporate capital structure?

The hypothesis that R&D investment is particularly constrained by cash flow has been suggested at a theoretical level by Leland and Pyle (1977), Bhattacharya and Ritter (1985), and Kihlstrom and Matthews (1984), all of whom argue that there is an inherent moral hazard problem in transferring information about a risky project from an entrepreneur (firm) to investors (shareholders) [but see Gale and Stiglitz (1986) for an argument that "good" entrepreneurs may prefer debt financing in a repeated game setting]. A more informal argument appears frequently in the business press, mostly couched in phrases such as "stock market myopia," meaning a failure of the market to value long term investments properly. It does seem somewhat plausible that the extreme riskiness of R&D projects and the difficulty and cost of revealing information about such projects might lead firms to prefer internal finance when they undertake them, to an extent which is not true of investments in physical capital.

Of course, all types of investment may be sensitive to the source of financing, and hence to the capital structure of the firm, both because of asymmetric information and because of the tax system. This has been most recently demonstrated by Fazzari, Hubbard, and Petersen (1988) among others, although the empirical fact has been known since the work of Meyer and Kuh (1957). The present paper provides additional evidence on the effects of liquidity constraints on ordinary investment and then asks whether R&D is <u>more</u> sensitive to shortfalls in retained earnings than ordinary investment.

Studying the correlation between any kind of investment and profits always raises the question of causality: in addition to providing a (possible) source of funds for investment, profits may be correlated with shocks which imply increased profit opportunities in the future and therefore with investment, which increases in response to this news. This too can lead to the substantial positive correlations between profit rates, the rate of return q, and changes in investment and R&D which have been observed. Thus we cannot be sure whether the apparent connection between liquidity (available cash flow) and investment of any kind is caused by credit constraints or by changes in expectations.

There are essentially two methods for investigating the "causality problem" in economic data: the model-free data-analytic approach of Granger and Engle, and the model-intensive approach which uses restrictions from econometric theory and structural modeling of the economic process to restrict the space of econometric results. In this paper, I focus on simple instrumental variable regressions which are more in the spirit of the first method than the second.

In an alternative approach to the problem,[1] I build an optimizing model of a firm which chooses an investment policy and a financial policy simultaneously in an environment with taxes, a new equity premium, and risk, and estimate the parameters of this structural model from the first order conditions. The results of that investigation were somewhat fragile and sensitive to the specification of the model and its timing; for this reason, I believe that the non-structural approach to this problem may also yield valuable insights.

The data which I use in this paper are firms from the publicly traded manufacturing sector from 1958 to 1987, a panel data set that I and others have analyzed in a series of papers (see Hall 1990a, 1990b, 1988a, 1988b; Bound et al 1984; Hall, Griliches, and Hausman 1986; Griliches, Hall, and Pakes 1987; and Hall and Hayashi 1988). I focus in the later part of the period, 1976 to 1987, for which I have over 1500 firms with data on capital stock, investment, R&D, and financial variables in an unbalanced panel; most of the results are presented for a subsample of about 1300 firms which have significant R&D programs. There is considerable overlap of this latter sample with the Fazzari, Hubbard, and Petersen sample, which consisted of about 400 manufacturing firms from Valueline for 1970 through 1984.

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[1]This method is described in a companion paper (Hall 1991b) which investigates the use of the Euler equation methodology for estimating the demand or investment of both types using micro panel data.

The paper begins with a discussion of the differences between ordinary investment and R&D investment: these differences are both intrinsic to the activities themselves and arise because of their treatment under the U.S. tax system. I then investigate the cross-sectional evidence on the relationship between the financial and real sides of manufacturing firms empirically and find that, contrary to Modigliani-Miller (1958, 1961), there is substantial evidence that the two are intertwined. The centerpiece of the paper investigates more carefully how this relationship evolves over time, using standard investment regressions; the specification of these regressions has been carefully chosen using modern specification tests designed for panel data (described in Appendix C of the paper) which attempt to ensure that the resulting equation is free of bias from simultaneity and omitted variables. The conclusion of these regressions is that cash flow itself, rather than sales, debt levels, or even Tobin's Q, is the primary factor influencing both kinds of investment over the medium term, although there is *contemporaneous* correlation between all these variables. The paper concludes with a summary and suggestions for future work.

2. The Cost of Capital and the Difference between Investment and R&D.

As I suggested in the introduction, there is reason to believe that the impact of financial considerations on the investment decision may vary with the type of investment. This section of the paper reviews these factors in more detail. To do this, I distinguish between purely financial (or tax-oriented) considerations which motivate the financing decision for any type of investment, tax considerations which may vary by type of investment, and other financial factors which may impact on the allocation of investment among competing alternatives.

The Modigliani-Miller theorem states that a firm which is choosing the optimal levels of investment should be indifferent to its capital structure, and should face the same price for investment and R&D investment on the margin. The last dollar spent on each type of investment should yield the same rate of return (after adjustment for nondiversifiable risk). Reason why this might not be true in practice have already been suggested: the cost of external capital may be higher than internal for information reasons, capital costs may differ by source of funds for tax reasons, and they may also differ across types of investments for both tax and other reasons.

Tax considerations which yield variations in the cost of capital across source of finance have been well articulated by Auerbach (1984) among others. He argued that under the U.S. tax system during most of its history the cost of financing new investment by debt has been less that that of financing it by retained earnings, which is in turn less than that of issuing new shares. More explicitly, if ρ is the risk-adjusted required return to capital, then

$$(1-\tau)\ \rho < \frac{(1-\theta)}{(1-c)}\ \rho < \frac{1}{(1-c)}\ \rho$$

over a wide range of tax parameters, where τ is the corporate tax rate, θ is the personal tax rate, and c is the capital gains tax rate. This inequality expresses the facts that interest expense is deductible at the corporate level, while dividend payments are not, and that shareholders formerly (prior to 1982) paid tax at a higher rate on the retained earnings which are paid out than on those retained by the firm and invested. It implicitly assumes that the returns from the investment made will be retained by the firm and eventually taxed at the capital gains rate rather than the rate on ordinary income.

Although the present U.S. tax system does not distinguish between capital gains and dividends, there are two reasons to believe that this ranking may still hold: first, to the extent that shareholders believe the capital gains rate will be restored at sometime in the future, they would expect the taxation of retained earnings to be somewhat lower than that of dividends. Second, and more important, asymmetric information problems between new investors and current shareholders and management may imply that firms which issue new shares must pay a lemons' premium, which will increase the required rate of return for this type of funding (Akerlof 1970, Fazzari, Hubbard, and Petersen 1988).

The proposition above applies to any type of investment which might be undertaken by the firm. There are two sources of divergences from this simple ranking for different types of investment. The first is generated by differences in tax rates faced by different kinds of investment: for example, the investment tax credit for equipment, or the tax credit on incremental R&D. The second reason for divergence is the one of interest here: the possibility that the true cost of capital before risk adjustment may vary by source of financing (for the information and lemons' problems mentioned earlier, or even because of deadweight bankruptcy costs in the case of debt finance). Note that if only the adjustment for nondiversifiable risk were in question, the firm might choose to invest less in risky projects, but the same financing hierarchy would be used for all projects. It is necessary that ρ change when a different source of financing is chosen for the ranking to be reversed. A theme of this paper is that the risk-adjusted cost of capital when retained earnings are the source of that capital may be enough less than the cost of capital when debt is the source that the tax wedge is eliminated for R&D investment (or even for ordinary investment), leading to an inversion in the financing hierarchy.

The tax treatment of R&D in the United States is *very* different from that of other kinds of investment: since R&D is expensed as it is incurred, the effective tax rate on R&D assets is substantially lower than that on either plant or equipment, with or without the investment tax credit in place (see Fullerton and Lyon 1987 for fuller discussion of the implications of this fact for tax neutrality). This effectively means that the economic depreciation of R&D assets is considerably less than the depreciation allowed for tax purposes -- which is 100 percent -- so that the required rate of return for such investment would be lower.

It is easy to make a simple calculation of the magnitude of this tax subsidy to R&D expenditure without the necessity of making assumptions about the stream of returns associated with R&D expenditure. When R&D (denoted R_t) is expensed, the cost of R&D to a tax-paying firm is simply

$$C_E = (1-\tau)\ R_t$$

When R&D is depreciated the cost is R_t followed by an infinite stream of tax deductions in the future. Discounted to the present, we may write this as

$$C_D = R_t - \tau\delta_R\ [1 + \beta(1-\delta_R) + \beta^2(1-\delta_R)^2 + ...]$$

$$= [1 - \tau\delta_R\ (1-\beta(1-\delta_R))^{-1}]\ R_t$$

where δ_R is the depreciation rate for R&D, and β is the firm's discount rate. The size of the subsidy per unit of R&D is given by

$$(C_D-C_E)/R_t = \tau(1-\delta_R)(1-\beta)/(1-\beta(1-\delta_R))$$

It is easy to see that this subsidy is zero when the tax rate is zero, the discount rate is unity (so that the pattern of depreciation deductions does not matter), or the depreciation rate for R&D capital is 100 percent (so that the economic life of R&D is the same as that assumed under expensing). The subsidy involved increases with the corporate tax rate, increases as the rate of economic depreciation falls, and increases as the rate at which firms discount their future streams of revenue increases. For example, if the discount rate is 0.9, the corporate tax rate is 0.5, and the private economic value of R&D assets depreciates at 25 percent per year,[2] the tax subsidy amounts to a modest 19 percent reduction in the cost of R&D investment relative to a tax system where R&D investment is depreciated at the economic rate rather than expensed. For the more conservative assumptions of a discount rate of 0.95 and depreciation rate of 15 percent, the reduction in cost is only 13 percent.

In addition, since 1982, there has been a tax credit available for incremental R&D expenditures (but see Eisner et al. 1984, Mansfield 1986, and Altshuler 1988 for evidence that the impact of this feature of the tax system has not been large). Thus another implication of the tax treatment of R&D is that firms which do not pay taxes should find the relative cost of R&D investment higher than those which do; this has to be taken into account when investigating the relationship of R&D to profitability.

Non-tax-motivated reasons for differing costs of R&D capital arise from a variety of sources:

1) Lemons' premia differ because investors have more difficulty distinguishing good projects from bad when the projects are long-term R&D investments than when they are more short-term or low-risk projects (Leland and Pyle 1977). Because the level of R&D expenditure is a highly observable signal under current Securities and Exchange Commission rules,[3] we expect that lemons' premia for R&D intensive firms will differ from those of other firms in a signaling equilibrium.

2) Firms do not like to reveal their innovation ideas to the marketplace and this fact reduces the quality of the signal they can make about the project; there is a cost

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[2]This depreciation rate is broadly consistent with the findings of a number of authors, including my own work (Hall 1988b), as well as work of Pakes (1978), Schankerman (1979), and Griliches (1980).

[3]Since 1972, publicly traded firms have been required to report their total R&D expenditures in their annual reports and 10-K filings with the SEC, under FASB rule No. ____.

to revealing information to their competitors (Bhattacharya and Ritter 1983).

3) Banks prefer to use physical assets to secure loans and are reluctant to lend when the project involves substantial R&D investment rather than investment in plant and equipment. In the words of Williamson (1988), "redeployable" assets are more suited to the governance structures associated with debt.

4) Managers are more risk averse than stockholders would wish them to be and avoid R&D projects which increase the riskiness of the firm (this last point is related to the previous; if bankruptcy is a possibility, managers whose opportunity cost is lower than their present earnings and potential bondholders may both wish to avoid variance-increasing projects which shareholders would like to undertake).

The first and second arguments imply that new equity finance is relatively more expensive for R&D, while the third implies the same thing for debt finance. Together these arguments suggest an important role for retained earnings, independent of their value as a signal of future profitability. The fourth argument suggests that firms where management is different from ownership will underinvest in R&D; this might be checked using data on the ownership share of management and the methodology of Friend and Lang (1988), who studied the impact of the ownership share on the debt-equity ratio, but this is left to future work.

3. Investment and Sources of Finance in the Cross Section.

I begin by investigating some of the facts about investment and R&D, in part to confirm and expand on the results reported in Hall (1990b). The empirical results in this paper are based on a panel of U. S. manufacturing firms from 1973 to 1987, which is described in Hall (1990a) and Hall (1990b). The panel includes essentially all publicly traded firms. Table 1 shows some characteristics of my sample.[4] Among firms who have R&D programs, the average firm has about two hundred million dollars of capital (geometric average) and invests twice as much in physical capital as in R&D. The firms retain about 85-90 percent of their cash flow on average (compare D/K to YR/K).

Investigation of the sample shown in columns 1 and 2 of Table 1 revealed that there were a few substantial outliers in the data; the origin of these outliers is not clear, but many appear to be due to reporting errors in the Compustat files, or incorrectly consolidated data. Because the ratio form of the investment equation which I am using is quite sensitive to extreme observations, I have trimmed the data using all the ratio variables shown in Table 1 by deleting all observations for which the value of one of these ratios was more than about five times the interquartile range away from the median. This removed about seven percent of the observations; the statistics on the trimmed data are shown in Table 1. This trimming did not affect the variance ratios in Table 2, but it does tend to eliminate some of the smaller firms.

Table 2 shows the variance decomposition of the growth rates of investment and R&D investment. Since profits, and therefore retained earnings fluctuate over the business cycle, an initial implication of the hypothesis that retained earnings are a preferred source of finance for R&D might seem to be that expenditures on R&D would fluctuate more highly than capital expenditures at the firm level (Stiglitz [1987]). In fact, quite the opposite is true, as Table 2 demonstrates (see also the evidence in Hall and Hayashi [1988], and Lach and Schankerman [1988]): in the U.S. manufacturing sector, the within firm variance of investment is almost twice that of R&D expenditures, and the variance of the growth rates is three times that of the growth rates of R&D. But, of course,

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[4]Appendix A gives more detail on how I determined the samples of firms used in the regressions. Table A1 in that appendix gives the number of firms available in each year.

this could easily be due to the quite different nature of the two types of investment; this difference can be roughly characterized in the following way: investment consists of equipment purchase and installation and plant construction, which means that most of the cost is expenditures on capital, which tends to come in lumps, whereas R&D investment is 50 percent labor (mostly scientists and engineers) (NSF 1985), which is not easily hired and fired without a substantial loss of "knowledge" capital, and hence might tend to be smoothed over time. That is, adjustment costs are higher for R&D capital.[5]

Table 3 and Figure 1 investigate whether the suggestion that debt may be an unsuitable form of finance for firms which are heavily invested in R&D capital relative to their overall capital stock. The table presents the correlation between two measures of R&D intensity with two measures of leverage. The two measures of R&D intensity are a flow measure, the current share of R&D investment (R) in total investment (R+I), and a stock measure which is constructed from my measures of physical and knowledge capital [G/(K+G)]. The stock of knowledge capital G has been constructed from the R&D investment series for each firm using a declining balance formula with depreciation rate of fifteen percent (see Hall 1990a for details). This means that the variation of this variable over the cross section will differ from that of R&D itself only to the extent that the R&D investment series of firms do not have identical growth rates.

Regardless of the measures used, in all cases the correlation is substantially negative, which is a very simple refutation of the most extreme form of the Modigliani-Miller theorem. Clearly the source of financing and the composition of assets are not independent. However, since R&D is a frequently a proxy for the future

[5]See Bernstein and Nadiri 1982 for an attempt to measure these costs in the profit function framework. Also see Himmelberg and Petersen (1990) for an argument similar to mine here.

growth prospects of the firm, and I expect these prospects to be correlated with the equity value of the firm, holding capital stock constant, the correlation coefficients based on leverage are probably biased upwards in absolute value. For this reason, I prefer to focus on the correlation between debt and R&D capital weighted by the overall capital stock of the firm, K+G. If debt B, physical capital K, and R&D capital G are the (depreciated) sums of past decisions on changes in debt, investment, and R&D where the debt changes and total investment are related, but debt changes are statistically independent of the *composition* of investment, it is possible to show that this correlation should be zero. It is robustly negative, as can be seen by examining its value for each year separately (bottom of Table 3 and Figure 1). That is, the overall movements in the equity market over time are not responsible for the observed negative correlation.

I also show (in the last column of the table and in Figure 1) the same time series for a sample of firms which remains the same over the fifteen year period, to investigate whether some of the variability we see in the series is due to the changing composition of the sample. The correlation for the balanced sample is more stable than that for the whole panel, but the average effect seems to be about the same.

Table 3 provides support for one hypothesis suggested in section 2 of the paper, that bondholders and banks prefer to use debt to finance *tangible* assets. However there are at least two possible other explanations for this result which I consider here: first, the possibility that substantial measurement error in the stock of R&D capital G will induce a negative correlation between G/K+G and B/K+G,[6] and second, the differential tax treatment of R&D and investment already discussed. I investigate the measurement error possibility in Appendix B using simulation techniques

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[6]This possibility was suggested to me by George Bittlingmayer.

because of the nonlinearity of the problem. The results are that for data distributed like mine, if the true correlation is zero but G has a multiplicative measurement error, the measurement error variance has to be at least twenty percent of the total in order to obtain negative correlations of greater than -0.1. Thus, although measurement error could help to explain the result, it would have to be implausibly large to get rid of it entirely.

The second possible explanation for my result is the following argument: because of the tax treatment of R&D, firms with large R&D programs will also be firms with lower taxable income, other things equal. This implies that the relative price of debt for these firms will not be as low as for firms with higher levels of taxable profits, since the deductability of interest expense is not a benefit if the firm does not pay taxes. To investigate this alternative explanation of the observed negative correlation between R&D intensity and leverage, I divide the firms in two different ways: first, those who have income taxes[7] in at least one of the five years preceding the measurement of the correlation and those who have not; and second, those firms which report an operating loss carry forward in one of the five years preceding, and those which do not.[8] If the correlation persists when I examine only firms which do not pay taxes or which have operating losses, that is confirmatory evidence that the effect is not due solely to tax considerations, but may also be due to the tangibility of a firm's assets.

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[7]The tax variable is Compustat data item 16, the total of all income taxes imposed by federal, state, and local governments. The operating loss variable is Compustat data item #52, the unused portion of the net operating loss carry forward.

[8]My initial investigation of this hypothesis used to the number of years in which taxes were paid or operating losses carried forward to classify the firms into six different groups. However, I found that firms with no taxes in at least one of the five years looked much alike, and slightly different from those who always paid taxes, while at the same time, firms with losses in at least one of the five years looked alike, and different from those who never experienced losses, so I chose to group the observations in the way shown in Table 4 to simplify the presentation.

Table 4 summarizes the results. Firms which do not pay taxes in at least one of five years preceding the measurement of debt and capital, or which have a loss carry forward in one of those five years have slightly higher "knowledge" capital intensities and higher debt to capital ratios than the other firms. These differences are consistent with the observation that both R&D and interest expense generate expense deductions against current profits, so that they increase the probability that the firm will not have taxable income. However, they appear to be substitutes rather than complements in the tax-reduction game, since the correlation between R&D capital intensity and the debt-capital ratio is almost the same for both groups of firms, and is very significantly negative, confirming the relative unimportance of debt finance for R&D-intensive firms.

As a final check of the hypothesis, I also ask whether the same correlation exists when the debt to physical capital ratio is compared to the R&D capital to physical capital ratio. If debt is being used solely to finance investment in ordinary capital, I would expect that there should be no relationship between the leverage of the firm measured in this way and the amount of R&D capital it possesses. This fact is again strongly confirmed in the data. For the 14,338 firms in the unbalanced panel, this correlation coefficient is 0.01, while for the 5084 firms in the balanced panel, it is -0.01.

In the next section of the paper, I investigate how this cross-sectional correlation arises from the relationship of investment and financing choices over time.

4. Investment and the Sources of Finance over Time.

This section of the paper looks at the properties of simple stylized investment regressions for ordinary investment and R&D. I use a functional form and a list of variables which is familiar from the investment literature and regress the ratio of investment to capital stock K on its own lag plus ratios of the beginning of period market value V to K (Tobin's q), sales Q to K, profits Y to K, and beginning of period long term debt B to K:

$$\left[\frac{I}{K}\right] = f\left\{\left[\frac{I}{K}\right]_{-1}, \left[\frac{V}{K}\right], \left[\frac{Q}{K}\right], \left[\frac{Y}{K}\right], \left[\frac{B}{K}\right]\right\}$$

This equation contains as special cases simple versions of the q model of investment (market value), the accelerator model (sales), and a model where liquidity constraints matter (profits).[9] I have augmented the model with a separate variable for debt (which is also a component of the market value variable) in order to explore more carefully the findings in Hall (1990b) and the previous section.

Naturally a variety of econometric issues such as simultaneity, unobservables, and measurement error arise, and therefore this section explores the impact of different specifications on the estimates. First, the choice of functional form (that is, the use of ratios) is standard in the investment literature and has the advantage of minimizing the heteroskedasticity in the data (since all variables are normalized by size) at the possible cost of increasing measurement error bias. Although I originally included the logarithm of size (K) in these regressions to check for non-homogeneity, the coefficient was almost invariably small and insignificant so I have omitted it.

Second, we expect that all these variables will be contaminated to a certain extent

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[9]In the tables which follow, I have measured profits as the cash flow available for investment; in order to treat ordinary investment and R&D investment symmetrically, this involves adjusting the normal cash flow variable, which is income available for common plus depreciation less taxes, for the R&D which has been expensed before it is computed. To do this, I have added back into this variable the after-tax R&D expenditures, which are the total R&D expenditures times one minus an estimated marginal rate of corporate tax. In the absence of detailed tax information, I have set this rate at zero if the pre-tax income of the firm is negative and at fifty percent if it is positive. This is crude and a more refined computation will be attempted in the future, but the actual differences between regressions using YR (my adjusted profits) and those using Y are not that great.

by measurement error. This error can be due to reporting error on Compustat as well as time aggregation effects at the individual firm level, but it can also be due to the extreme heterogeneity across the firms in the sample: for any given variable, such as investment, for example, we are really comparing apples and oranges when we look across firms, due to composition effects. Except for the K variable, for which even simple measurement error is likely to be correlated over time, data recording errors are easy to control for by using lagged values of the variables as instruments. The second type of error, which arises from the heterogeneity of the data sample, is less easy to get rid of. To the extent that it is permanent and additive, I can control for it by using differenced estimates, which remove a fixed firm effect.

Interpretation of the investment regression proposed above is also clouded by the simultaneous nature of the relationship: the q model of investment, for example, is an equilibrium relation between investment rates and Tobin's q. There is no reason to think that expectational and other errors in investment and market value are uncorrelated, although this problem is mitigated by the use of a beginning of period measure of the market value V. Similarly, although it may be plausible to believe that the causality between *contemporaneous* profits or sales and investment goes in one direction, the same cannot be said for debt levels and investment. Any financing hierarchy model of investment strategy will predict that debt levels and investment are under simultaneous control by the firm, which implies that there can be feedback between the debt and investment choices.

In Appendix C, I explore the use of different instrument lists and their effect on the estimates of my basic regression, both in levels and in first differences.[10] From

[10]Note that I have measured the investment rates in percent to avoid having many non-significant zeros in the reported regression coefficients. This multiplies all the coefficients of the independent variables except the lagged dependent variable by 100.

the specification tests which I conducted in that appendix, I concluded that the best specification of the model was in first differences and uses lags two and three of the level variables to correct for simultaneity bias and measurement error. However, the price of achieving consistency in the parameter estimates is an increase in the standard errors which renders all of the predictor variables insignificant except for the lagged endogenous variables and possibly the profits variable. Thus the fairly strong relationships between contemporaneous changes in sales, market value, debt and investment which appeared in the ordinary least squares estimates here and in my earlier work (Hall 1991a) seem to be due to simultaneous movements in all the variables. Only the profits variable remains significant when I correct for the contemporaneous correlation due to this simultaneity; this argues for a liquidity constraint interpretation of the results, since it says that a firm's investment this period responds to forecastable increases in cash. Unless adjustment lags are very long (more than two years), one would have expected investment to respond sooner if it was only reacting to changes in expectations about profitability.

This "liquidity" effect is quite sizable; using the estimates where I have dropped sales from the equation in Table 5,[11] the calculated elasticities of investment and R&D with respect to profits at the means of the data are 0.46(.12) and 0.28(.08) respectively. That is, a forecastable 10 percent increase in profits leads contemporaneously to an increase in each type of investment of 3 to 5 percent. The

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[11]This is justified by appealing to the fact that profits and sales are both attempts to measure the same underlying variables, demand shifts and liquidity shifts, and inspection of the instrumental variable results reveals that profits does a much better job; when sales does come in, it is usually with a small and negative coefficient, which inflates the positive profits coefficient due to their correlation. When profits is dropped from the equation, sales enters with a smaller, but significant positive coefficient. In other words, there is no real independent information in predictable sales; it is just a noisier indicator of the underlying variable.

relation is symmetric, of course, and decreases in profits imply similar declines in investment. Note that there is no evidence here that this effect is more important for R&D than for ordinary investment; in fact, it seems to be the other way around. Table 5 also demonstrates that I need only a single variable, either growth in profits, growth in sales, *or* growth in market value to capture this effect once permanent differences across firms are controlled for. When all three variables are included, the one for profits dominates, whereas when profits is dropped, sales dominates market value in explaining investment. Only when market value is included without sales or profits does this variable become significant; this result holds for both ordinary investment and R&D investment.

The fact that decreases in profits are associated with decreases in investment is relevant to the interpretation of the debt coefficients. Recall that one of the starting points for this paper was the finding that substantial increases in leverage were followed by cuts in both kinds of investment over the next several years. This stylized fact is visible in the ordinary least squares estimates in the first column of Table C2, although in the cross section (the last column of Table C1), the evidence was that debt is irrelevant to R&D policy, and weakly positively associated with investment policy. The negative coefficient persists when the first differenced estimates are instrumented, but becomes smaller and quite insignificant. If it were simply the case that a separate impact of debt disappears because it works through increases in interest expense (which appear in profits) then I would expect the debt coefficient to increase in absolute value when I use sales as the profitability indicator (column 4 of Table 5). If anything, the result goes the other way.

How can this result be reconciled with the apparently large declines in investment following increases in debt levels documented in my earlier work (Hall 1991a, 1990b)? Note first that the findings can be summarized by saying that a regression of predictable investment changes on predictable debt changes in the presence of profit changes does not yield a significant coefficient, whereas unpredictable changes in debt levels do seem to be followed by investment cuts. I interpret this as saying that when a firm has time to plan or adjust, it can undo the effects that debt has on its liquidity; on the other hand, in the first year or two after substantial increases in leverage, the changes in debt have a sizable short run impact on investment policy. This view emphasizes the transitional effects of leverage increases, which have also been documented by Kaplan (1989b) for the case of leveraged buyouts.

5. Conclusions.

This paper represents an introductory exploration into the differences and similarities between investment and R&D investment in large publicly traded manufacturing firms. The following facts have emerged: First, the unsuitability of debt as a source of finance for R&D investment has been confirmed in the cross section; firms with heavy debt loads are not and have not been R&D-intensive firms in the past. Second, the only strong relationship between debt levels and investment policy is the one documented in my earlier work (Hall 1990b and Hall 1991a): contemporaneous changes in debt levels are inversely related to both kinds of investment, but the relationship is one of simultaneity and is either transitory or at least unexpected. Forecastable debt changes are not related to investment shifts. I have interpreted this result as confirming the transitory effects of leverage increases on a firm's investment policy, which have also been found in some of the case studies of this kind of transaction.

Third, there is evidence that liquidity matters substantially in these data, but more for ordinary investment than for R&D. Forecastable profit increases are associated with increases in both kinds of investment; this could still be a demand effect, but it would require fairly long lags (more than two years) between demand shocks and investment responses for this to be the case. An additional argument in favor of the liquidity interpretation is that the profits variable wins the horse race between

Tobin's q, sales and profits in predicting changes in investment levels. If the story were all demand expectations, such a result would be surprising.

On the negative side, the regressions reported here have pushed the nonstructural investment equation in a panel data setting about as far as it can go. In spite of the very large sample with which I am working, the results are discouragingly fragile (although I have only reported those which are robust) and the standard errors large. To make further progress in exploring the hypotheses about R&D investment financing suggested earlier in the paper, I suggest two avenues: 1) Augment the list of instruments with tax or other price variables which have some variation across firms. This appears to be a promising avenue in the case of R&D investment (see Hines 1991 for results which suggest this approach might be fruitful). 2) Use a more fully structural approach for analysis of the implications of the liquidity constraint hypothesis and the tax system; although actual estimation of this kind of model using the Euler equation approach has proved problematical, it is useful for deriving implications of the model. I plan to pursue both of these approaches in future work.

TABLE 1

SAMPLE CHARACTERISTICS

U.S. Manufacturing Firms 1973-1987

	Untrimmed Data		Trimmed Data		R&D Performers (Trimmed Data)			
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Min	Max
Obs[1]	25,373 (2546)		23,477 (2499)		14,325 (1678)			
I/K	.097	.080	.093	.067	.101	.075	.002	.449
R/K	.036	.086	.030	.048	.047	.055	.001	.349
Q/K	1.895	1.148	1.842	.952	1.850	.869	.017	9.71
Y/K	.104	.191	.111	.112	.120	.121	-1.79	1.11
O/K	.184	.200	.187	.144	.200	.164	-1.55	1.77
YR/K	.140	.182	.140	.127	.167	.143	-1.65	1.33
D/K	.018	.052	.019	.050	.020	.033	0.0	2.45
B/K	.305	.296	.295	.213	.273	.193	0.0	1.50
V/K	6.682	82.216	1.157	1.163	1.254	1.360	.105	24.12
K[2]	101.4	1.98	117.5	1.93	171.0	2.03	0.43	77,219.
G	13.0	2.26	14.3	2.26	23.0	2.06	0.01	17,970.

Variables:

I —— Capital expenditures by the firm during the year.
R —— R&D-expenditures by the firm during the year.
Q —— Sales during the year.
Y —— Cash flow, income available for common plus depreciation, less taxes.
O —— Cash flow, operating income before depreciation and taxes.
YR — Cash flow available for investment = Y plus after-tax R&D expenditures.
D —— Dividends paid out by the firm during the year.
B —— Long term debt outstanding at the beginning of the year.
V —— Market value at the beginning of the year (debt plus equity).
K —— capital stock of the firm, adjusted for inflation as described in Hall (1990a).
G —— The "knowledge" capital of the firm, constructed from the R&D investment as described in Hall (1990a).

Notes to Table:

[1]The total number of firm-years of data, with the number of firms in parentheses.

[2]Geometric mean. In columns 1 and 3, the mean of G is computed over the positive observations only (17,937 and 14,168 observations respectively).

TABLE 2

VARIANCE DECOMPOSITION OF INVESTMENT AND R&D

1600 Manufacturing Firms 1974-1987
(12,446 observations unbalanced)[3]

	Log Investment	Log R&D	Ratio of Variances
Total	4.80	4.21	0.88
Total within year	4.78	4.15	0.87
Variance within industry & year[4]	3.82	3.59	0.94
Variance within firm & year	0.329	0.203	0.62
Variance of first differences[5]	0.368	0.109	0.30

Notes to Table:

[3]This is the same sample as the R&D-performing sample of Table 1, but with fewer observations because of the growth rate computation, which requires one lag of investment and R&D spending.

[4]The industries are at the two-digit manufacturing level (20 industries).

[5]Since variables are in logs, the variance of first differences is approximately the variance of the (real) growth rates.

TABLE 3

LEVERAGE RATIOS AND R&D CAPITAL

1973-1987

Correlation Coefficients

	All R&D Firms (1678 Firms)		Balanced Panel (324 Firms)	
	R/(I+R)	G/(K+G)	R/(I+R)	G/(K+G)
B/(B+E)	-.150	-.228	-.096	-.204
B/(K+G)	-.109	-.216	-.111	-.242

Correlations of (B/(K+G),G/(K+G)) by Year

Year	Number of R&D Firms	Correlations: R&D Firms	Correlations: Balanced Panel
73	929	-.136	-.180
74	1010	-.248	-.262
75	1041	-.156	-.224
76	1044	-.200	-.276
77	1022	-.175	-.297
78	1003	-.193	-.282
79	1007	-.205	-.259
80	984	-.185	-.212
81	972	-.169	-.182
82	965	-.223	-.207
83	968	-.250	-.175
84	925	-.232	-.212
85	898	-.262	-.278
86	831	-.256	-.279
87	726	-.267	-.290
Total	14,325	-.216	-.242

Variables:

I — Capital expenditures by the firm during the year.
R — R&D expenditures by the firm during the year.
E — Market value of equity at the beginning of the year.
B — Long term debt outstanding at the beginning of the year.
K — The capital stock of the firm, adjusted for inflation as described in Hall (1990a).
G — The knowledge capital of the firm, constructed from the R&D investment series using a methodology described in Hall (1990a).

TABLE 4

LEVERAGE RATIOS AND R&D CAPITAL BY TAX STATUS

1978-1987

Correlation Coefficients

All Firms (9,223 obs.)

	R/(I+R)	G/(K+G)
B/(B+E)	-.188	-.268
B/(K+G)	-.105	-.213

	Taxpaying[6] Firms (6,858 obs.)		Non-taxpaying Firms (2,365 obs.)	
	R/(I+R)	G/(K+G)	R/(I+R)	G/(K+G)
B/(B+E)	-.254	-.311	-.197	-.339
B/(K+G)	-.154	-.250	-.071	-.216

	Firms with no NOLCF[7] (7,049 obs.)		Firms with NOLCF (2,174 obs.)	
	R/(I+R)	G/(K+G)	R/(I+R)	G/(K+G)
B/(B+E)	-.243	-.315	-.151	-.290
B/(K+G)	-.138	-.245	-.102	-.244

Notes to Table:

[6] Taxpaying is defined as having had income taxes payable in each of the five years preceding when the ratios were calculated. Non-taxpaying firms did not pay taxes in at least one of those years.

[7] Firms with no NOLCF had no net operating loss carryforwards in any of the five years preceding when the ratios were calculated. Firms with NOLCF had an operating loss in at least one of those years.

TABLE 5

INVESTMENT REGRESSIONS - FIRST DIFFERENCES

1247 Firms: 1976-1987 (Unbalanced Panel of 8,845 Observations)

Dependent Variable = ΔI/K (in percent)

$\Delta(I/K)_{-1}$	.234 (.031)	.231 (.032)	.225 (.026)	.203 (.024)	.203 (.027)
Δ(V/K)	1.28 (.98)	1.37 (.96)	1.22 (.89)	1.47 (.81)	3.50 (.87)
Δ(Q/K)	-2.48 (3.80)	-1.58 (4.27)	-	5.09 (1.17)	-
Δ(YR/K)	39.27 (20.37)	-	27.92 (7.16)	-	-
Δ(Y/K)	-	37.32 (24.72)	-	-	-
Δ(B/K)	-1.98 (2.73)	-2.41 (2.65)	-1.61 (2.45)	-1.07 (2.16)	-3.00 (2.31)
Std.err.	7.51	7.36	7.07	6.54	7.11

Dependent Variable = ΔR/K (in percent)

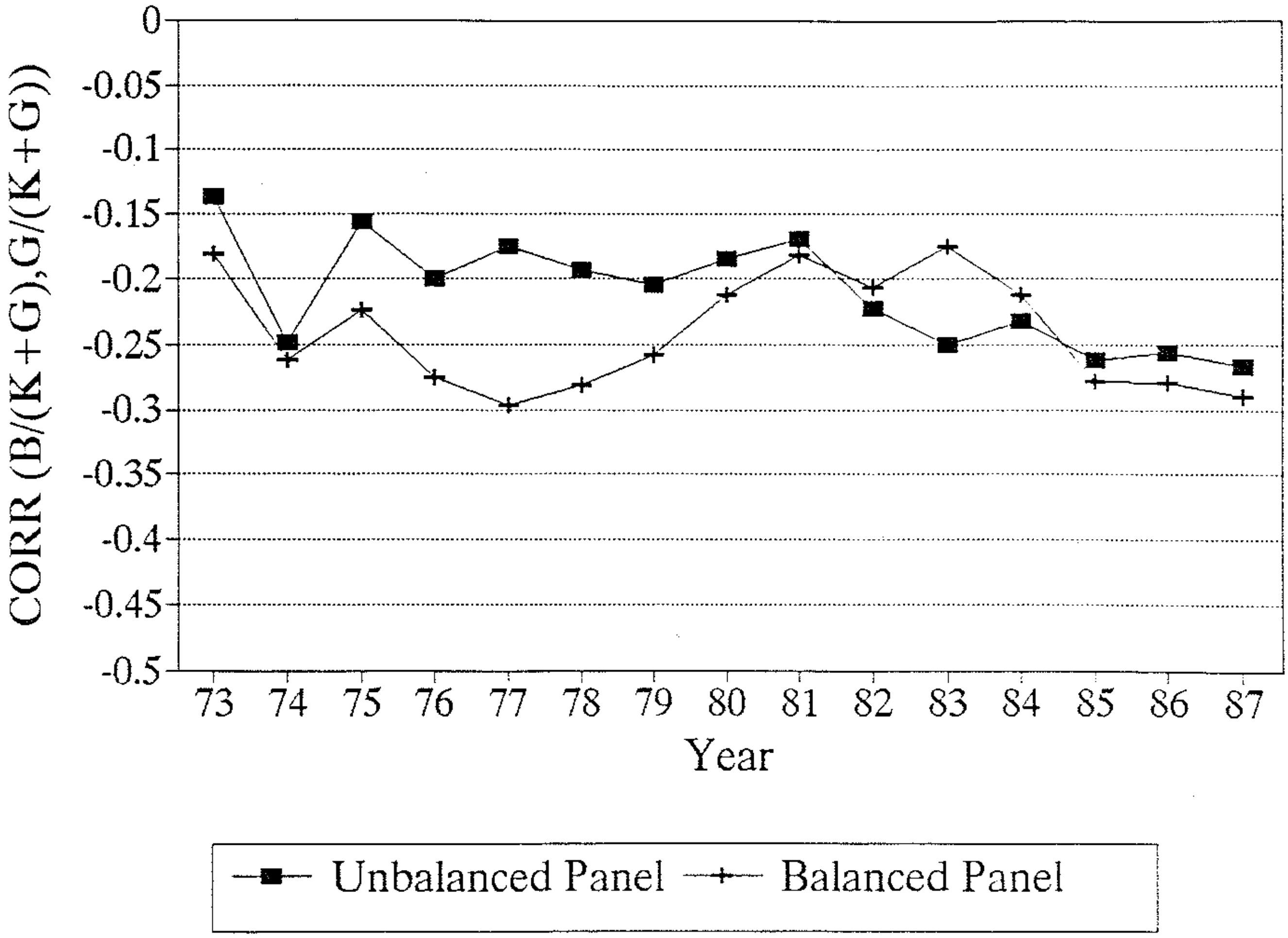
$\Delta(R/K)_{-1}$	.307 (.105)	.267 (.088)	.235 (.069)	.190 (.059)	.220 (.065)
Δ(V/K)	.28 (.42)	.30 (.32)	.15 (.03)	.24 (.23)	.81 (.22)
Δ(Q/K)	-2.34 (1.42)	-.80 (1.45)	-	1.35 (.36)	-
Δ(YR/K)	18.50 (7.65)	-	8.03 (2.39)	-	-
Δ(Y/K)	-	11.61 (8.23)	-	-	-
Δ(B/K)	-.96 (1.04)	-.95 (.86)	-.65 (.74)	-.57 (.66)	-1.03 (.71)
Std.err.	2.16	1.81	1.63	1.49	1.63

All estimates are instrumental variable estimates with instruments I/K, R/K, Y/K, Q/K lag two and three, B/K, V/K lag one, two, and three, and year dummies.

Heteroskedastic-consistent standard errors are shown in parentheses.

Variables are described in Table .

Figure 1
Correlation of Leverage and R&D Capital



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APPENDIX A

CONSTRUCTION OF THE DATA SAMPLE

The sample is drawn from a panel of U. S. manufacturing firms constructed at the National Bureau of Economic Research from Compustat data. This panel contains approximately 2500 firms with up to 30 years of data each from 1958 through 1987. A complete description of the panel and variables is given in Hall (1990). For the investigations in this paper, the primary period of interest is the late seventies and eighties, so I have defined the sample to be an unbalanced panel of all firms from 1976 through 1987, with data back to 1973 if possible, so that I can have three lags for all the variables. The first two columns of Table A1 shows the number of firms available in each year of data from 1973 through 1987 in the raw data file and then the number of firms after observations without good data on the key variables are deleted.

As I discussed in the body of the paper, estimation of linear regressions with ratio variables is extremely sensitive to outliers in these variables, whether due to measurement error or some restructuring upheaval. I therefore trimmed the data by excluding observations with ratios outside of five times the interquartile range above or below the median. The trimming values for each variable are shown at the bottom of Table A1, and the number of observations remaining in each year is in the third column of the table.

The paper's analysis is based only on firms which perform a significant amount of R&D; this sample is about sixty percent of the whole sample, and it is shown in the last two columns of Table A1. The first column shows the number of firms available for the cross-sectional studies in Tables 3 and 4 of the paper, and the second column shows the number of firms available if I restrict the sample to firms with at least five years of good data, so that I can use three lags in the regressions (because I use beginning of year values of the stock variables capital K, R&D capital G, debt B, and market value V, I need one extra year of data to get three lags).

TABLE A1

SELECTION OF THE SAMPLE

Year	Raw Data File	Untrimmed Sample	Trimmed Sample: Including non-R&D Firms	Trimmed Sample: R&D Firms only	Trimmed Sample: R&D Firms only, 3 lags or more
1973	2058	1656		929	788
1974	2193	1723		1010	853
1975	2209	1767		1041	899
1976	2212	1811	1328	1044	936
1977	2156	1804	1364	1022	922
1978	2102	1802	1365	1003	913
1979	2069	1786	1348	1007	904
1980	2052	1776	1346	984	881
1981	2007	1735	1342	972	877
1982	1978	1708	1324	965	868
1983	1976	1723	1316	968	870
1984	1900	1677	1286	925	838
1985	1824	1599	1232	898	773
1986	1700	1456	1142	831	687
1987	1522	1298	1055	726	577
Total	29,958	25,373	23,477	14,325	12,586
# Firms	2,726	2,546	2,499	1,678	1,247

Variable	Description	Trimming Values: Minimum	Trimming Values: Maximum
I/K	Investment-Capital ratio	0.001	0.45
R/K	R&D-Capital ratio	0.001	0.35
G/K	R&D Capital intensity	0.001	2.0
Q/K	Sales-Capital ratio	0.0	10.0
Y/K	Profits-Capital ratio	-2.0	2.0
O/K	Op. income-Capital ratio	-2.0	2.0
V/K	Tobin's Q (market to book)	0.1	25.0
B/K	Long-term Debt-Capital ratio	0.0	1.5

APPENDIX B

MEASUREMENT ERROR IN R&D CAPITAL - A SIMULATION ANALYSIS

This appendix evaluates the effects of measurement error in the R&D capital G on the correlation of G/(K+G) and B/(K+G). If the true correlation were zero, but G was measured with error, a quick glance at these expressions suggests that it might be possible that a negative correlation would be measured in the data. However, it is not easy to derive that result analytically, particularly since the likely form of the measurement error is proportional, that is,

$$G = G^{*}e^{w}$$

where G^{*} is true R&D capital, and w is the measurement error, distributed normally with mean zero and variance σ^{2}. I therefore chose to evaluate this possibility by using simulation techniques.

I began by assuming that B (debt) and $(K+G^{*})$ were jointly lognormally distributed with means (3.7,5.5) and covariance matrix (4.7,3.9,4.0) taken from the data; an eyeball test suggested that lognormal was not a bad assumption. I then assumed that the share of R&D capital, $G^{*}/(K+G^{*})$ was distributed independently of both the other variables (B and $(K+G^{*})$), using the empirical distribution function of G/(K+G) to generate its values (since it was not easy to find a standard distribution function to approximate the distribution of this type of share variable). This set of assumptions would be implied if debt was being used to finance the total net capital stock (correctly measured), but without reference to its composition. If G were correctly measured, the calculated correlation of B/(K+G) and G/(K+G) using these simulated values should be zero, and this was confirmed by the simulation.

To evaluate the effects of measurement error, I computed the correlation over a range of measurement error variances all the way from zero to 100 percent of the observed variance of log G, using 10,000 draws per simulation. The results are shown in Table B1. Sensitivity analyses using variations in the distributional assumptions did not change these basic results much. The conclusion is that measurement error would have to be quite large, of the order of the variance in G itself (across firms) in order for measurement error alone to come close to accounting for the observed effect.

However, it is true that the estimates reported in the body of the paper are likely to be slightly biased downward (away from zero) by the fact that our measure of G is imperfect. I also experimented with a measurement error whose mean was nonzero; this has no effect on the measured correlation.

TABLE B1

SIMULATION WITH MEASUREMENT ERROR IN G

σ^2	σ^2/σ^2_G	Corr(G/(K+G),B/(K+G))
0.0	.00	.010
.49	.05	-.029
.70	.10	-.055
.85	.15	-.073
.98	.20	-.105
1.10	.25	-.106
1.21	.30	-.110
1.30	.35	-.138
1.39	.40	-.132
1.48	.45	-.142
1.56	.50	-.139
1.63	.55	-.154
1.71	.60	-.162
1.78	.65	-.155
1.84	.70	-.159
1.91	.75	-.149
1.97	.80	-.157
2.03	.85	-.154
2.09	.90	-.165
2.15	.95	-.155
2.20	1.0	-.141

APPENDIX C

THE ECONOMETRIC SPECIFICATION OF THE INVESTMENT EQUATION

This appendix reviews the specification testing which led to the form of the investment and R&D investment equations which are presented in the body of the paper. The specification of equations with right hand side endogenous and lagged endogenous variables in a panel data setting is complicated, and the consequences of misspecification are likely to be important; a review of the estimates presented in this appendix will underline the fact that coefficient estimates can vary widely and even change sign over different specifications, so that it is important to have a methodology for choosing the set of assumptions on the disturbance to the equation which give the most robust results.

The equation I am interested in estimating has the typical form of a dynamic panel data equation:

$$\text{(B1)} \qquad y_{it} = \gamma y_{it-1} + X_{it}\beta + \alpha_i + \delta_t + \varepsilon_{it} \qquad i = 1,\ldots,N; \qquad t = 1,\ldots,T$$

where y_{it} is the investment rate,[1] X_{it} is a matrix of (possibly) endogenous variables, α_i is a firm specific effect, δ_t is a year specific effect common across firms, and ε_{it} is the within firm and year disturbance. The only instruments available for X_{it} and y_{it-1} are further lagged values of these variables. The specification questions which arise are many: 1) Is ε_{it} heteroskedastic? 3) Is ε_{it} autocorrelated? 3) Are there fixed effects, that is, is α_i correlated with the regressors? 4) What are the appropriate instruments (if any) for X_{it} and y_{it-1}? This appendix contains a series of tests which answer these questions. I have made one assumption at the outset, based on prior experience with these kinds of data: that the "year effect" δ_t can be treated as a fixed effect by including a set of time dummies in all the regressions and instrument lists. Although this is an innocuous assumption for the linear specification examined

[1]Throughout the discussion, I will refer to the dependent variable as investment, but everything I say also applies to the R&D investment equation, which is treated in parallel to the ordinary investment equation.

here, it does exclude any macro-style analysis of common impacts across firms, as well as removing inflation and interest rates at the economy-wide level from the list of potential instruments.

The order in which I perform the specification tests on this investment equation is the following: first I conduct tests on the instrument sets for both the level and the first-differenced versions of the model. After choosing a specification based on the results of these tests, I check the residuals for signs of serial correlation, since its presence would invalidate my instruments, which are lagged values of the right hand side variables. Throughout this process I compute heteroskedastic-consistent standard errors, as well as computing the Breusch-Pagan Lagrange-multiplier test for size-related heteroskedasticity by regressing the estimated squared residuals on the logarithm of the capital stock. In all cases this test rejects homoskedasticity with a negative sign; that is, the variance of the disturbances in both regression equations is inversely proportional to the size of the firm, which is not that surprising.[2]

In Tables C1 (levels) and C2 (first differences) I explore the specification of the investment regressions with different instrument lists. I have used Hausman-style tests here, since they can be performed using unbalanced panel data, but the results of these tests can also be interpreted as GMM tests of various degrees of exogeneity as in Keane and Runkle (1992) or Schmidt, Ahn and Wyhowski (1992). Later on in this appendix I use this alternative methodology to test for exogeneity in two subsets of the data which are balanced.

The instruments used are lagged values of the right hand side variables; these instruments are highly likely to meet the requirement that they be correlated with the right hand side variables, but it is more problematical to maintain that they will not be correlated with the true disturbances. In the case of the level regressions, given the presence of fixed effects, they will almost surely be invalid. In both cases, time aggregation problems and the presence of a lagged dependent variable suggest that at least the lag one instruments will be invalid. In the regressions shown in Tables C1

[2]Of course, strictly speaking, not all of these tests are consistent, since it appears that not all of the specifications produce consistent estimates of the equation coefficients, but the results are so uniform across equations that I have confidence that a small amount of size-related heteroskedasticity exists and is fairly orthogonal to the rest of the model, implying that correcting the standard errors for its presence is sufficient.

and C2, I find evidence of both these effects; first, a Hausman test for the correlation of the right hand side variables with individual firm effects rejects resoundingly with a $\chi^2(17)$ equal to 957 and 2269 for the investment and R&D equation respectively. Second, in each successive column of the tables, I remove a set of lags from the list of instruments (for the OLS estimates in column 1, I have effectively included lag zero, one, two, and three), and display a pseudo F-statistic for the validity of the instruments which are removed. This test is asymptotically equivalent to a test of differences between the estimated coefficients in the two columns. In the case of the level estimates, this test never accepts, although of course it cannot evaluate the validity of the last instrument set, which includes only variables from three years earlier. For the first differenced estimates, however, the test fails to reject the instrument list which includes variables lagged twice in favor of one which includes only variables lagged three times.

Given the results of the tests for instrument validity, my preferred specification for the investment equation in the body of the paper is based on the first differenced estimates which use lag two and three variables as instruments for all the right hand side variables. Note that although the results of this set of specification tests is indifferent between using lag two instruments or not, the coefficient standard error estimates worsen significantly if I confine the list of instruments to the lag three variables only; hence the preference for the former list. What about the estimated residuals from this specification: do they support the use of lagged variables as instruments? The first three estimated correlation coefficients for the investment equation are (.42, .04, .04) and for the R&D equation they are (.47, .14, .11). This suggests that although there is some residual autocorrelation at lags two and three, the bulk of it is in the first lag, where I also found the instruments to be inappropriate. This result reinforces my preference for a fixed effects model with lag two and three instruments, at least in the absence of truly exogenous instruments.

Although as we have seen, they cannot generally be given a "causal" interpretation, the regressions in Tables C1 and C2 are also informative about the correlation patterns present in these data. First, it is quite clear that treating all the variables in the model as endogenous makes a difference to the estimates. The most important change in both level equations is that sales is insignificant when predictable sales is used rather than actual sales (columns 2, 3, and 4 vs. column 1 of Table C1). It is possible to interpret this result as saying that news (unexpected changes) in sales has a strong immediate impact on investment of both types, due to revisions in demand expectations or even liquidity considerations, but that the predictable component of sales increases is already incorporated into the profits variable, which remains significant even when instrumented, while sales itself does not. This interpretation is supported by the first-differenced results in Table C2, where the ordinary least squares estimates of the effects of changes in sales on changes in investment of both types is positive, while the fully instrumented results show a marginally significant negative coefficient for changes in sales and a very large positive coefficient for changes in profits.[3]

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[3]It is also supported by a regression of the "news" in investment on the "news" in sales and profits, where news is defined as that portion of the variable which is not predictable from the past history of investment, profits, sales, debt, and market value. This regression shows a strong positive relationship between surprises in both kinds of investment and surprises in sales; and a much weaker insignificant relationship to surprises in profits.

TABLE C1

INVESTMENT REGRESSIONS - LEVELS

1247 Firms: 1976-1987 (Unbalanced Panel of 8,845 Observations)

Est. Method	OLS	Inst. List 1*	Inst. List 2*	Inst. List 3*
	Dep. Var. = I/K (in percent) St.dev. = 6.70			
$(I/K)_{-1}$	.418 (.009)	.391 (.015)	.674 (.030)	.811 (.049)
(V/K)	41 (.07)	.05 (.18)	-.27 (.17)	-.26 (.18)
(Q/K)	91 (.08)	.07 (.11)	.05 (.11)	-.05 (.12)
(YR/K)	14.68 (.61)	25.02 (1.89)	10.18 (2.93)	2.44 (3.92)
(B/K)	-1.32 (.32)	.05 (.43)	.47 (.57)	1.31 (.72)
Std.err.	5.24	5.34	5.59	6.03
Pseudo-F**	104.5	53.9	11.0	
B-P Test***	138.3		----	
Test for Correlated Effects****			956.8	
	Dep. Var. = R/K (in percent) St.dev. = 4.82			
$(R/K)_{-1}$	.924 (.004)	.940(.011)	.978 (.012)	.996(.013)
(V/K)	.11 (.02)	.25 (.05)	.14 (.06)	.14 (.08)
(Q/K)	.18 (.02)	-.07 (.03)	-.06 (.03)	-.09 (.04)
(YR/K)	2.59 (.18)	.37 (.66)	-3.20 (.89)	-3.80 (1.39)
(B/K)	.01 (.10)	-.24 (.16)	-.20 (.23)	.03 (.27)
Std.err.	1.55	1.58	1.70	1.73
Pseudo-F**	150.0	83.9	25.1	
B-P Test***	1247.1		----	
Test for Correlated Effects****			2269.0	

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