The Financing of Technological Change

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Research in Business Economics and Public Policy, No. 10

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The Financing of Technological Change

by
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UMI RESEARCH PRESS
Ann Arbor, Michigan

Produced and distributed by
UMI Research Press
an imprint of
University Microfilms International
A Xerox Information Resources Company
Ann Arbor, Michigan 48106

Library of Congress Cataloging in Publication Data

Switzer, Lorne, 1954-
The financing of technological change.

(Research in business economics and public policy ; no. 10)
A revision of thesis (Ph.D.)—University of Pennsylvania, 1982.
Bibliography: p.
Includes index.
1. Technological innovations—finance. 2. Research. Industrial—Finance. 3. Federal aid to research.
I. Title. II. Series.
HC79.T4S94 1985 338'.06 85-16419
ISBN 0-8357-1689-9 (alk. paper)

To my parents

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Acknowledgments

First and foremost, I would like to thank Professor Edwin Mansfield for his tireless encouragement and support of these studies. I would also like to thank Professors Richard Easterlin, Almarin Phillips, Pablo Spiller, Oliver Williamson and Anthony Romeo, as well as Omar Ashur, for their contributions at various stages of the research. Thanks are also due to numerous executives for their cooperation in providing data.

I would especially like to thank my wife Marsha for her devotion and enthusiastic support, and my wonderful children Sarede and Andrew for the inspiration they provided.

I am grateful for the financial assistance I received from Professor Mansfield through a grant to him by the National Science Foundation.

Finally, I would like to thank the journals *Management Science*, *Research Policy*, *R & D Management*, and the *Review of Economics and Statistics* for permission to include material that first appeared in their pages.

Introduction

Technological change has played an important role in the growth of industrialized countries in the past century. Financing technological change is an important challenge that faces most nations of the world. In a mixed economy, the resources available for undertaking investments to promote technological change are not present in unlimited supplies at zero cost. Both governments and firms often face severe budgetary restrictions which limit their spending in particular areas. This challenge has two aspects.

First, firms may face restrictions on the resources they devote to R & D and innovation given their internal cash flow limitations and the potential competing uses of funds, as well as capital market restrictions. Government policy may play a role in alleviating this constraint through direct subsidization of firms or through tax credit schemes. The effects of such policies to firms will depend in part on the complex interaction between the sources and uses of funds within the firm as well as the additional constraints on firm behavior imposed by the government.

The second and related aspect of this financial challenge is the determination of the absolute level of investments in new technology required by the firm in order to meet the competition at home and abroad. Budgeting for a given level of commitment to innovation in any given year will be dependent on the costs of innovation, as well as the rate of change over time of these costs. The use of appropriate cost deflators is essential for sound budgeting.

To a great extent these issues have been neglected in the extant literature. However, policy makers have become increasingly cognizant of them. One of the first pieces of legislation enacted by the Reagan administration in its first term was to provide companies with tax credits for increased R & D spending. To the extent that private R & D expenditures are responsive to cash flow effects, such legislation may have its desired effects. The cost of such legislation, of course, is the addition to the mounting deficit caused by forgone tax revenues.

An alternative approach to fostering technological change is direct government support of private R & D. Proponents of this course of action would argue that the forces of complementarity between public and private R & D spending overwhelm any tendencies towards substitutability. Also, they might argue that the costs of this measure in terms of its additions to the deficit be more easy to quantify relative to the tax credit approach. Policy makers in the Canadian government have increasingly favored this approach, though it has lost adherents in the U.S.

It is clear that in dealing with the problems of financing innovation, policy makers within firms and within the government should be guided by realistic models of firm behavior as well as adequate data. This book represents an attempt to provide both in examining the relevant issues.

Our agenda will be as follows. In chapters 1 and 2, we will examine the problem of financial restrictions facing firms in undertaking investments in new technology, and the effects and costs of the government stimuli of direct expenditures and tax credits.

In chapter 1, a general flow-of-funds model explaining aggregate R & D investment behavior along the lines established initially by Dhrymes and Kurz (1967) is developed and estimated using company level data in the U.S. The approach generalizes a number of previous models by allowing for simultaneous interaction between alternative uses of the firm's investment funds and the sources and uses of investment funds. Several conclusions will emerge relating to:

(a) the importance of internal funds relative to external financing for R & D;
(b) the opportunity cost of R & D expenditures relative to capital outlays;
(c) the crowding out of public expenditures by private expenditures; and
(d) the potential impact of direct tax credits including the relationship between the revenue loss to the government and the R & D stimulation induced—the analysis here will be supplemented with references to additional evidence we have obtained in a separate study relating to Canada (a country which has had a fairly long history of tax credits for R & D that are quite similar in nature to the recent U.S. legislation).

The analyses of chapter 1 primarily use firm data and it might be remarked that in examining topics such as the implications of government financing on particular areas of technology such as energy or health, a higher degree of disaggregation is required. Thus in chapter 2 we will proceed to focus on the issue of the effects of government financing of R & D in the important area of energy, using project level data that we have obtained in a field study.

Since the early 1970s, government support of energy R & D conducted in the private sector has been rising at a rapid rate—in fact at a rate that has exceeded all other government R & D budget functions. The rationale for the increased level of government support is that the private sector acting alone will underinvest in energy R & D owing to risk aversion and/or limitations on appropriability of returns. Also, since 1973, the motive of national security has been at the forefront of government decisions regarding energy R & D. Government policy has ostensibly emphasized the support of projects that are long term and high risk ventures, and that are more likely to complement, rather than substitute for, private R & D efforts. To this date, only anecdotal evidence has been forthcoming to allow one to assess whether government funded energy R & D projects conducted in the private sector actually stimulate further private R & D outlays, or instead serve as a retardant to private R & D. Based on the analyses conducted for our sample, we hope to shed some light on this issue in chapter 2.

In chapter 3 we will shift our attention to the problem of the changing costs of investments in innovation in the recent past. At present, none of the cost deflators available to firms or the government is entirely adequate. The Battelle Memorial Institute publishes an annual "cost of research index" based on the methodology developed by H. Milton (1966, 1972) that for reasons to be discussed in this chapter, has severe drawbacks. The National Science Foundation in the U.S. uses the GNP deflator, a measure that is also potentially unreliable. It is essential that more adequate deflators be developed. We will thus proceed in this chapter to construct a number of cost deflators for both industrial R & D as well as industrial innovation, using project level as well as company level data. The data have been amassed from companies that accounted for about one-ninth of all company funded R & D in the U.S.; one of the main objectives of the analysis is to evaluate the nature and extent of biases that ensue when one chooses to rely on the usual proxies for costing R & D. Another objective is to demonstrate a fairly tractable approach which managers could use to infer the rate of increase in relative R & D costs over time using actual expenditure data.

The study then concludes with a review of the main findings and presents some suggestions for further work.

1

Investing in R & D: The Problem of Alternative Sources and Alternative Uses of Funds

Introduction

In this chapter, the firm's R & D budgeting decision process is cast within a simultaneous equation flow-of-funds framework. When a firm invests in R & D it frequently has to balance the potential returns against their costs, in terms of competing uses of funds. In addition, the firm's investments must be financed somehow, either externally through capital markets or through internally generated funds. These constraints have largely been ignored in previous work on the R & D investment decision process. In this study they are made explicit.

The approach here contrasts with most previous work that follows the presumptions of standard financial theory appearing in introductory textbooks. In the standard approach, investment decisions (including investments in technological change) may be dichotomized from financial considerations and investment decisions can be made sequentially, without regard to alternative uses of funds. For the simple textbook approach to be valid, some very restrictive and untenable assumptions must be imposed, such as an absence of market imperfections (which would include investor trading costs, limitations on personal borrowing, personal tax biases, informational costs, flotation costs, agency costs, asset indivisibilities, and limited markets) and bankruptcy costs. Theoretically, it has been demonstrated that once the former are accounted for, clear interdependencies between financing and investment as well as between alternative forms of investment appear.[1] Once bankruptcy costs are recognized, debt management becomes a salient area of concern for corporate managers.[2]

Schematically, the general approach taken here is shown below in figure 1. Unlike much previous work the approach endogenizes or links simultaneously five key decisions/constraints within the firm: the capital expenditure decision (investment in plant and equipment), the R & D investment decision, the dividend payout decision, the external financing decision (constraint) and the internal financing constraint. Previous work has often looked at the R & D decision in isolation

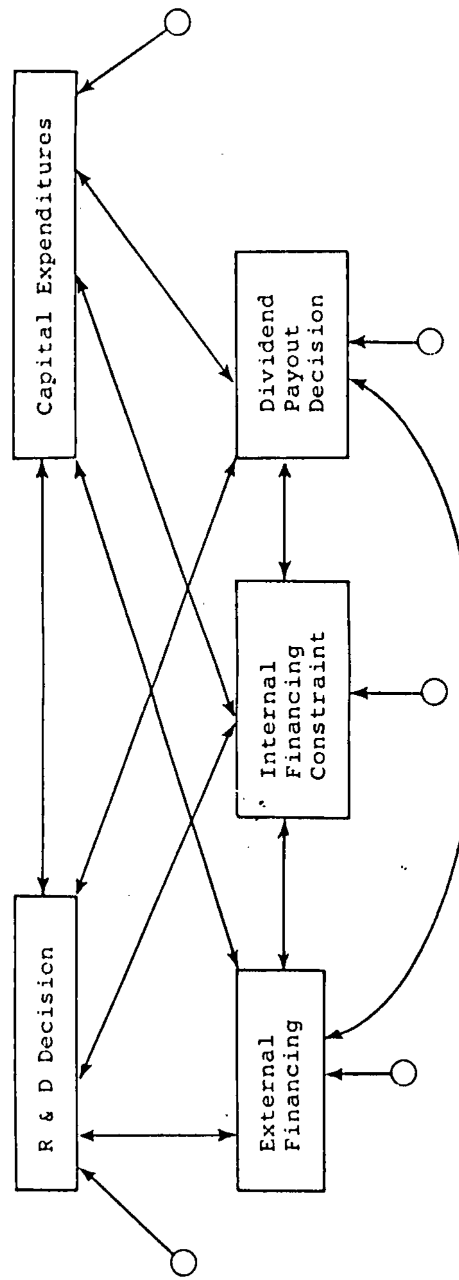

Figure 1. A Schematic Representation of the Model[1]

[1] Rectangles denote endogenous variables (determined within the system) while circles represent exogenous variables.

or has failed to account for competing uses of firm's R & D investment and/or the external financing option (constraint).

The Model

Description of the System

The structural schemata chosen might be viewed as a synthesis of the financial flow approaches to modeling capital investment which to date have ignored the simultancity of the R & D and capital expenditure decisions (for example, Dhrymes and Kurz (1967), and McCabe (1979)) with the simultaneous equation models of investment in R & D that have ignored the simultaneity of investment and financing decisions (Mueller (1967), and Grabowski and Mueller (1972)).

Briefly, the system endogenizes the firm's R & D expenditures, its capital expenditures, its dividend payments, new debt financing and internal financing, and consists of the following equations:

(1) $RD_i = h_1 (I_i, DIV_i, ND_i, IF_i, CR_4, CRT_i, G_i, DST_i, RDY_i)$
(2) $I_i = h_2 (RD_i, DIV_i, ND_i, CF_i, DS_i, DS5_i, INT_i, K_i, IY_i)$
(3) $DIV_i = h_3 (RD_i, I_i, ND_i, PRTS_i, \text{DIVY}_i, GRT_i, VAR_i, NY_i)$
(4) $ND_i = h_4 (RD_i, I_i, DIV_i, CFT_i, RISK_i, PRA_i, BETA_i)$.

With the added identity (*I*) $IF_i \equiv RD_i + PRB_i + DEP_i$, where the endogenous variables are

RD_i = company funded R & D expenditures[3] by firm *i*;
I_i = capital expenditures for firm i;
DIV_i = dividend payments of firm *i*;
ND_i = new long-term debt financing of firm *i*;
IF_i = internal financing of firm *i*;

and the exogenous variables are

PRB_i = profits before taxes of firm *i*;
DEP_i = depreciation and depletion allowances of firm *i*;
CR_{4i} = average of the four-digit four-firm concentration ratios of firm *i*'s industries of classification;
CRT_i = $(CR_{4i})^2$;
G_i = government R & D awards to firm *i*;
DST_i = ten-year change in sales (1967-77) for firm *i*;
RDY_i = previous years R & D expenditures of firm *i*;

CF_i = after-tax profits plus depreciation and depletion allowances for firm i (lagged 1 year);
DS_i = one-year change in sales of firm i;
$DS5_i$ = five-year change in sales (1972–77) of firm i;
INT_i = average interest rate of firm i (total interest payments to total long-term debt outstanding);
K_i = lagged capital stock of firm i;
IY_i = lagged investment of firm i;
$PRTS_i$ = current profits after taxes of firm i;
$DIVY_i$ = lagged dividends of firm i;
GRT_i = long-term growth in firm i's earnings per share (measured over nine years 1968–77);
VAR_i = standard deviation of firm i's earnings to net worth (measured over a five-year period 1972–77);
NY_i = a dummy variable representing the exchange listing of the company's common stock (equals one if the listing is NYSE and zero otherwise);
CFT_i = after tax profits plus depreciation and depletion allowances for firm i (unlagged);
$RISK_i$ = coefficient of variation of firm i's after tax profits plus depreciation and depletion allowances (measured over the five-year period 1972–77);
PRA_i = the ratio of lagged profits after taxes to total assets for firm i; and
$BETA_i$ = firm i's systematic risk.

This system can be justified in two ways. First, one may argue, as did Dhrymes and Kurz, that "technological and marketing constraints are exogenous to the system and predate the decision process we wish to study."[4] Once we admit the cash flow constraint into such a system, McCabe notes we get the implication that "sources of funds would affect uses of funds positively, and other sources negatively, and conversely."[5]

Secondly, and perhaps more insightfully, (1)–(4) can be derived as equilibrium conditions explicitly from a system of first order conditions for utility maximization in the spirit of Grabowski and Mueller.[6]

Selection of Exogenous Variables

With regard to the choice of exogenous variables to identify the equations of the system, we have in general selected regressors which have explained with some success the behavior of the endogenous variables here in, for the most part, single equation formulations. Thus, the contribution of the approach lies in its examination of the effects of the variables in the context of a simultaneous equation formulation.

The R & D equation. Previous studies of the determinants of R & D investment have emphasized variables which have served as proxies for rate of return and appropriability characteristics. Cash flow, denoted as the sum of after-tax profits plus depreciation and depletion allowances lagged one period, is frequently used to account for possible aversion to external financing of R & D and to serve as an expected returns proxy in line with the reasoning used in support of tax concessions for R & D. However, such treatment ignores the contemporaneous nature of the cash flow constraint to the firm. To capture this in the approach here, internal financing (IF) is specifically embodied as an endogenous constraint, and is expected to have a positive effect on firm R & D investments.

Four-firm concentration CR4 was considered as a means of testing the neo-Schumpeterian approach, though with some reservations. The neo-Schumpeterian position is perhaps most vehemently propounded by J. K. Galbraith, and asserts that large size and structural monopoly provide the most favorable atmosphere for technological progress. It is a variant of Schumpeter's view that transient monopoly, as opposed to competition, is required for progress.[7]

The squared value of this term was also used to test a "diminishing returns" variant of the neo-Schumpeterian approach. Given the somewhat ambiguous evidence of the effects of concentration on R & D in single equation formulations (for example Comanor, Link) as well as in Levin's simultaneous model, no prior prediction on the sign of this coefficient was made.

Next, government support of R & D was included to test the complementarity vs. substitutability arguments that have been raised for government R & D. Given the recent Levin (1980) and Link (1982) findings for fairly recent periods, some degree of complementarity was expected a priori. Inferring the effects of government expenditures on private R & D on the basis of regression analysis using aggregative data is a highly tentative procedure, though. In the next chapter, we will address its shortcomings in more detail and will provide alternative evidence regarding the effects of government expenditures using project level data for energy R & D.

The firm's ten-year change in sales (1967–77) was included to capture uncertainty and demand pull effects recognizing the alternative potential interpretations of this variable.[8]

Finally, lagged R & D was included as a predetermined variable to account for partial adjustment effects, in the spirit of Mansfield's model (1964). Mansfield's explanation for the lagged adjustment process implied by the use of this variable is as follows.

> First, it takes time to hire people and build laboratories. Second, there are often substantial costs in expanding (R & D expenditures) too rapidly because it is difficult to assimilate large

> percentage increases in R & D staff. . . . Third, the firm may be uncertain as to how long expenditures of (desired R & D levels) can be maintained. It does not want to begin projects that will soon have to be interrupted.[9]

The capital expenditures equation. As the main focus of this chapter is concerned with the determinants of nominal R & D investment, an exhaustive review of previous work on the capital investment equation will not be provided. Suffice it to note that Jorgenson relates that the flexible accelerator mechanism has been the "point of departure of the large body of empirical research on investment behavior."[10] In this approach, he notes "changes in desired capital are transformed into actual investment expenditures by a geometric lag function . . . "[11] Hence, if we were to focus on gross investment using this schemata, assuming a constant rate of depreciation we get a functional form such as:

$$I_{G_t} = (1 - \lambda)\,(K_t^D - K_{t-1}) + K_{t-1}$$ [12]

where I_{G_t} ≡ gross investment in year t
K_t^D ≡ desired capital stock in year t
K_t ≡ actual capital stock in year t
$(1 - \lambda)$ ≡ the adjustment coefficient.

The alternative theories of investment that have appeared are thus based on different views on the determinants of K^D, the desired capital stock. Jorgenson recognizes three main approaches:[13] (a) the external financing approach, (b) the internal financing approach, and (c) the output or capacity utilization approach. Supporters of (a) would assert that the optimal investment level is determined by the firm's marginal cost of funds, proxied by some external interest rate. Firms are seen to be quite willing to resort to external financing (when it is available) when pressures on capacity appear. Proponents of (b) would argue that desired capital stocks should be affected by internal funding since at the point where internal sources of funding are depleted (the usual state of the world), the marginal cost of capital schedule becomes highly inelastic. On the other hand, supporters of the capacity utilization approach assert that increased output (proxied by increased sales) are the primary cause of net investment, with financial constraints of no importance. Given the somewhat mixed evidence on the performance of the various theories, all of them will be given some consideration in what follows.

Thus, to account for the capacity utilization approach, one-year and five-year changes in the firm's sales are included as regressors. Next, the cash flow term used in the R & D equation is also incorporated into the capital expenditures equation to account for the internal funds approach. In addition, the firm's average interest rate (measured by the firm's total interest payments divided by long term debt outstanding) is included as a proxy for the firm's relevant interest rate, to account for the external financing approach (as a supplement to the endogenous variable, new debt financing). As with Dhrymes-Kurz and McCabe, its inclusion

was due to the absence of an alternative, more accurate, measure of the phenomenon of interest.

Since the equation measures gross investment, the lagged value of the firm's capital stock was used to deal with the effects of replacement demand. As Mueller notes (1967, 66), this variable will "act as an index of the capital intensiveness of the firm relative to other firms in the sample and not as a measure of its present level of capital relative to some ideal quantity [in reference to the Griliches time series approach]." Hence, it is expected that its coefficient will be positive, as was found for example in McCabe's cross sections (1979, 130).

Additionally, lagged investment was also included to account for partial adjustment effects, as discussed in reference to the R & D equation.

The dividend equation. Perhaps the most important work concerning dividend policy that has appeared in the literature is that of J. Lintner (1956). Lintner specified an empirical model in which firms are seen to set dividends in terms of a long-run payout ratio and speed of adjustment[14]; the predominant element which affects current changes in dividends, given the targeted payout ratio, is simply the firm's net earnings after taxes. The model is written as:

(L1) $$D_{it} = a_i + c_i(D_{it}^* - D_{i,t-1}) + U_{it},$$

where D_{it} ≡ actual dividend payments of firm i in period t
D_{it}^* ≡ desired dividend payments of firm i in period t
c_i ≡ speed of adjustment coefficient
U_{it} ≡ random error term

Desired dividend payments are written as:

(L2) $$D_{it}^* = r_i P_{it},$$

where r_i ≡ target payout ratio of firm i,
P_{it} ≡ current profits after taxes for firm i.

Substituting (L2) into (L1) we get the equation:

(L3) $$D_{it} = a_i + b_i P_{it} + d_i D_{i,t-1} + U_{it},$$

with $b_i = c_i r_i$
$d_i = (1 - c_i)$,

which has been used quite successfully to explain dividend behavior in the past. In fact, some authors have claimed that it "stands among the more thoroughly founded hypotheses in the area of business behavior."[15]

As a further test of this model, current profits after taxes and lagged dividends were adopted as regressors in the dividend equation. Two additional variables used by Grabowski and Mueller (1972) to account for managerial discretionary behavior were also incorporated into the model. The first of these is the firm's long-run growth in earnings per share (measured over a nine-year period);[16] this variable might be expected to lower the level of dividend payments to the extent that growth reflects favorable opportunities for the use of retained earnings (allowing the firm to bypass capital markets for investment purposes). Second, the standard deviation of the firm's ratio of earnings to net worth (measured over a five-year period, 1973–77) was used to account for the presumption that managers attempt to counterbalance the dangers to their security posed by high earnings variability by increasing dividend payouts. In the presence of such behavior, then, this variable can be expected to have a positive coefficient in the model.

The final variable considered in this equation is the exchange listing of the company's stock to account for the claim that NYSE stocks tend to have higher dividend payouts than do AMEX or OTC stocks.[17]

The new debt equation. The new debt equation has received little attention in the literature. A traditional view of the firm's new debt management policy is that an optional debt level exists which balances the tax gains from increasing leverage against the costs associated with the increased probability of bankruptcy as the firm's fixed costs rise.[18] As was mentioned earlier, we have used the firm's BETA as one measure of riskiness and which may be expected to have a negative effect on debt financing. Also, following McCabe, the firm's coefficient of variation of after tax profits plus depreciation was used as a supplementary risk measure.

The firm's cash flow, measured by its level of current after tax profits plus depreciation and depletion allowances was used as in Dhrymes-Kurz and McCabe to capture the firm's need for preserving solvency, and was expected to have a negative sign. Finally, the ratio of the firm's profits to total assets lagged one period was used to capture capital market rationing effects. The notion is that firms with higher rates of return on their assets may have easier access to external financing; hence the expected sign of this variable is positive.

Description of the Data

The data used to estimate the system were derived for a cross section of 125 manufacturing firms in 1977.[19] The industries chosen are chemicals, petroleum, electronics and aerospace. In terms of the selection of individual firms, we have attempted to provide fairly thorough coverage of the various industries, trying to avoid capturing only the largest firms. Completeness of the data was the ultimate criterion for inclusion in the sample; nevertheless, by including industries that had quite variable research intensities (both high and low), a sample that possesses some of the characteristics of manufacturing industry as a whole has been obtained.[20]

Estimation

The model given by linearized versions of the functions h_1, h_2, h_3, and h_4 in our description of the system was estimated for the pooled sample of 125 firms for 1977 using three techniques—ordinary least squares (OLS), two-stage least squares (2SLS), and three-stage least squares (3SLS); the latter approach which accounts for identity (I) as well in the estimation, given our theory, is the consistent procedure, yielding estimates that are asymptotically equivalent to full information maximum likelihood estimates. Dummy variables[21] were included in each equation not captured in the included regressors. As in previous studies of this sort, all of the endogenous variables, as well as the size-related exogenous and predetermined variables were deflated[22] by firm sales to account for the potential for heteroscedasticity and the problem of "extreme values." Since all of the equations of the system are overidentified, and the covariance matrix of the residuals was found to be nondiagonal, it may be most appropriate to discuss the model in terms of the 3SLS estimates in Tables 1.1 and 1.2.

Estimates of the R & D equation. First, looking at the R & D equation, as with a number of previous models (e.g., Link (1982), Grabowski (1968), Grabowski and Mueller), internal financing seems to be one of the central determinants of R & D expenditures.[23] The importance of internal financing is further highlighted by the lack of significance of the coefficient of new debt, which seems to support the contention that external financing of R & D is unimportant due to, e.g., disclosure requirements and the absence of collateral value for R & D outlays.

The evidence here provides indirect support for potential beneficial effects of tax credits embodied in the Economic Recovery Tax Act on R & D expenditures. For to the extent that tax credits enhance firms' internal financing capabilities, they may have their desired effects of stimulating private R & D.[24]

As with the Levin (1980) and Link (1982) studies, neither the concentration varible nor its square appeared significant, which seems to undermine a variant of the simple neo-Schumpeterian theory.

The ten-year change in sales variable provides support for the expectations theories of Mueller (1967) and others. Lagged R & D is also found to be significant, lending some support for a partial adjustment mechanism for R & D, though this result has to be interpreted with caution.[25] The coefficient for capital expenditures is similar to the Mueller and Grabowski-Mueller estimates. Also, the lack of significance of dividends is consistent with Grabowski-Mueller as well as

Table 1.1. Three-Stage Least Squares Estimates of the R & D and Capital Expenditures Equations

R & D Equation			Capital Expenditures Equation		
Independent Variable	Estimated Coefficient	Absolute *t*-Ratio	Independent Variable	Estimated Coefficient	Absolute *t*-Ratio
I	−0.003	1.302[d]	*RD*	0.057	0.416
DIV	0.119	0.959	*DIV*	0.089	0.146
ND	0.004	0.206	*ND*	0.126	0.988
IF	0.025	1.453[d]	*CF*	0.071	0.410
CR4	−0.016	0.606	*DS*	−0.107	2.563[a]
CRT	0.012	0.396	*DS5*	0.023	0.682
G	0.084	0.922	*K*	0.058	1.812[c]
DST	0.009	1.886[c]	*IY*	0.501	3.253[a]
RDY	0.707	20.375[a]	*INT*	−0.015	0.717
D1	−0.007	2.759[a]	*D1*	0.011	0.715
D2	0.003	1.135	*D2*	−0.005	0.408
D3	0.004	1.000	*D3*	−0.005	0.303
Constant	0.001	0.172	Constant	0.009	0.390
GOF	0.962		*GOF*	0.635	

Note: The goodness of fit measure (GOF) is the square of the correlation coefficient between actual and fitted values (Haessel (1978)).
[a]Statistically significant at the 0.01 level.
[b]Statistically significant at the 0.05 level.
[c]Statistically significant at the 0.10 level.
[d]Statistically significant at the 0.20 level.

Mueller's results. Next, from the sign and significance of the coefficient of D_1, it is apparent that firms in the petroleum industry tend to have lower R & D to sales ratios than do firms in other industries.

Finally, consistent with the recent results of Link, Levin, Terleckyj and Levy (1982) and Mansfield and Switzer (1984), no evidence of complete crowding out of private expenditures by government expenditures could be observed. The coefficient of government expenditures exceeds minus one by a highly significant margin, which implies that social R & D expenditures (i.e., public plus private expenditures) rise for an increase in government outlays, pari passu. This result is quite robust with respect to the specification of the exogenous variables in the model, as well as to the method of estimation.

Estimates of the capital expenditures equation. Looking now at the capital expenditures equation, it is apparent that our results are quite consistent with earlier models.[26] Although the cash flow term usually had a positive coefficient in the various specifications tried, it was never significant. The accelerator or capacity utilization hypothesis for capital expenditures seems suspect, given the negative and significant coefficient for the one year change in sales variable, a result consistent with McCabe (1979). Both the sign and significance of the new debt term

Table 1.2. Three-Stage Least Squares Estimates of the Dividend and New Debt Equations

Dividend Equation			New Debt Equation		
Independent Variable	Estimated Coefficient	Absolute *t*-Ratio	Independent Variable	Estimated Coefficient	Absolute *t*-Ratio
RD	0.001	0.240	*RD*	0.252	2.254[b]
I	−0.018	3.607[a]	*I*	0.457	4.140[a]
ND	0.018	2.373[b]	*DIV*	−0.785	1.171
PRTS	0.018	2.644[a]	*CFT*	−0.218	1.406[d]
DIVY	1.042	31.163[a]	*PRA*	0.613	5.749[a]
GRT	0.0002	0.399	*RISK*	0.002	0.635
VAR	0.0005	1.058	*BETA*	−0.031	2.836[a]
NY	0.0005	1.019	*D1*	0.002	0.144
D1	−0.001	2.430[b]	*D2*	0.015	1.242
D2	−0.001	2.436[b]	*D3*	−0.017	1.012
D3	−0.002	1.836[c]	Constant	−0.011	0.540
Constant	0.003	3.720[a]	*GOF*	0.415	
GOF	0.944				

[a]Statistically significant at the 0.01 level.
[b]Statistically significant at the 0.05 level.
[c]Statistically significant at the 0.10 level.
[d]Statistically significant at the 0.20 level.

are consistent with the conclusions of Dhrymes-Kurz and McCabe. Additional weak support for an external financing hypothesis for capital investment is given by the negative coefficient for the interest rate variable, though this variable is difficult to interpret with confidence and, like McCabe's result, is not significant.

The firm's lagged capital stock variable appears to be capturing the effects of replacement demand, as expected. From the lagged investment variable, it appears that actual investment responds to changes in desired levels only gradually, though the speed of adjustment is much more rapid than for R & D. Finally, dividend outlays do not seem to be significant determinants of capital expenditures. Overall the absence of significance of financing variables (*ND, DIV*) contrasts with Dhrymes-Kurz's and McCabe's general results, though not with Fama (1974), and appears to provide some support for the Modigliani-Miller perfect capital markets model.

Estimates of the dividend equation. Proceeding now to the dividend equation in Table 1.2, it is quite clear that Lintner's claim (1956, 106) that "investment requirements as such (have) little direct effect in modifying the pattern of dividend behavior" is not validated here. Lintner's approach may be brought into question by the fact that the reaction coefficient for dividends is not significantly different from zero (since the coefficient of lagged dividends is not significantly different from 1).

New debt and current profits had a positive and significant effect as expected. Long-term earnings prospects, to the extent that they are reflected in growth in earnings per share appear to have no influence on dividend outlays, which contrasts with the Grabowski-Mueller result. The earnings variability term has a positive sign, as would be predicted by the managerial discretion hypothesis of Grabowski-Mueller, though, unlike them, we found that it lacked significance. No strong evidence could be found in support of the claim that stocks listed on the NYSE are more "dividend intensive" than others for 1977. Finally, as in Dhrymes and Kurz, the industry dummy variables appear significant, and thus we might assert, as they do (1967, 458), that "it would not appear proper to deal with this (dividend) relation in simple aggregation terms [à la Lintner]. At least this aspect of inhomogeneity must be taken account of. . . ."

Estimates of the new debt equation. With respect to the new debt equation, current cash flow had a negative effect (as expected), indicating perhaps the solvency preserving function of new debt. Current capital expenditures were positive and significant determinants of new debt issues, which is consistent with McCabe and Dhrymes-Kurz. Somewhat surprisingly (though not from the flow of funds perspective), the coefficient of R & D was also positive and significant. What these results seem to imply is that new debt essentially serves an accommodative role. Once firms decide on their R & D and investment commitments, outside capital will be sought to the extent that it is available. However, the initial commitment to invest does seem to be related to the means of financing. In particular, firms apparently prefer to finance R & D internally.

The profit rate term behaved as expected, providing further support for the Dhrymes-Kurz hypothesis (1967, 462) that there exists "noninterest credit rationing" where more profitable firms have easier access to credit markets. The firm's systematic risk, measured by the *BETA* term, also behaved exactly in accordance with our expectations. The supplementary risk variable serves essentially no meaningful purpose in the model, as was also found by McCabe. The dividend term was unexpectedly negative, as was found in the Dhrymes-Kurz model, as well as in McCabe, perhaps owing to the absence of lasting tangible value of dividends, unlike capital expenditures. Another possible interpretation, adduced by Dhrymes-Kurz (1967, 462), is simply "the fact that stock flotation is an alternative to bond flotation."[27]

Summary and Conclusions

In this chapter we have attempted to model for the first time, using U.S. data, the determinants of R & D investment within the context of a flow of funds,

simultaneous equation framework. This approach generalizes a number of previous models of the R & D investment decision process that have appeared in the literature by allowing for simultaneous interaction between alternative uses of R & D funds (dividends and capital expenditures) and between the sources and uses of funds.

Four key observations might be noted. First, although previous models have often recognized the importance of internal funds for supporting R & D programs, and have hinted at the unimportance of external financing for R & D, this is the first model to appear that has perhaps quantified both phenomena. Second, although some previous studies using American data have concluded that R & D expenditures may lower the marginal returns on capital outlays, our results show no such effects. Also, consistent with recent evidence of other authors, no evidence of crowding out of private expenditures by government expenditures could be found. This result is fairly robust to alternative specifications of the exogenous variables of the model, as well as to alternative methods of estimation. Finally, in contrast with Dhrymes-Kurz and others, but consistent with Fama (1974), the Modigliani-Miller result of independence of capital investment from financing could not be rejected in the simultaneous procedures, as opposed to the single equation results.

2

The Costs of Government Support of R & D: The Case of Energy

Introduction

The problem of measuring the costs and effects of government funding on private research and development has not been addressed to any significant extent in the industrial organization literature on the economics of technological change in the past twenty years. This is unfortunate. As M. Kamien and N. Schwartz remarked in a famous survey paper, "since antitrust, patent and copyright law and government financing (all) may influence the course and rate of technological advance, determining how they do so is of interest to policy makers as well as theorists."[1]

The rationale for government funding of R & D in industry usually proceeds along the following lines. First of all, many research activities have pure public good attributes associated with them. For example, as E. Mansfield remarks, "collective consumption activities such as national defense and the space program involve the Federal government as the sole or principal purchaser"[2] of the final goods and services. Since the Federal government has the primary responsibility in these activities, he notes "it must also take primary responsibility for the promotion of technological advance in the relevant areas."[3]

Second, the Federal government may intervene in areas where the private sector would underinvest in R & D for goods normally purchased in the private sector. As the *Economic Report of the President* of 1972 relates, R & D often entails nonappropriable rents, especially for basic research. The report claims, "although an investment in R & D may produce benefits exceeding its costs from the viewpoint of society as a whole, a firm considering the investment may not be able to translate enough of these benefits into profits on its own products to justify the investment."[4] Mansfield clarifies this point further. "The results of R & D can be appropriated only to a limited extent because of the riskiness and costliness of R & D. . . . Industrial firms will invest [in basic research] less than is socially optimal since the results are unpredictable and usually of little direct value to the firm supporting the research although potentially of great value to society."[5,6]