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15 The R & D and Investment Decision and Its Relationship to the Firm's Market Value: Some Preliminary Results

Uri Ben-Zion

15.1 Introduction

Earlier work on R & D expenditures in firm cross sections has suggested that the market value of a firm reflects the R & D stock of R & D intensive firms (see Ben-Zion 1978 and Griliches 1979).

Recently Griliches (1981) has extended this analysis to a time-series context, using a time-series, cross-sectional model of a firm's market valuation. He tested the within-firm effects of R & D investment (and changes in R & D) on changes in market value of a firm and found that only "unexpected" changes in R & D affect the market value of a firm. These results are consistent with the financial literature on "market efficiency."

The purpose of this paper is to focus on the relationship between R & D, patents, net investment, and the market value of the firm. It is part of a broader plan to analyze the interrelationships between production, investments, market demand, and financial variables (see Ben-Zion 1980).

Grunfeld (1960) emphasized the role of expectational variables, such as the market value, in the determination of investments by individual

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firms. His work was extended to a "macro" model of investment by Griliches and Wallace (1965) and Ben-Zion and Mehra (1980). Schmookler (1966) looked at the interrelationship between series of patent output and investment in different industries, emphasizing the time pattern of different series, on the basis of which he conjectured the direction of causality.

Another direction of research, more microdata based, has been pursued by Mansfield and his associates. Their research uses more detailed data as well as more informal "inside information."[1]

In this paper, I present a simple framework for the analysis and testing of the interaction between corporate decision variables in response to changing market conditions. The emphasis here is on the determinants of market value and the rate of return. It is closely related to the work of Ariel Pakes (this volume) and Jacques Mairesse and Alan Siu (this volume), who also deal with the interaction between related sets of a firm's variables.

15.2 Interaction between the Firm's Decision Variables

A firm is assumed to maximize a "target" function subject to market and production constraints.[2] As a solution to the above optimization problem, a firm simultaneously determines its plans with repect to investment, R & D, and other variables. At the same time, on the basis of the available relevant information for the firm and the general market (e.g., interest rate, inflation, tax policy), the stock market determines the price of the firm's securities and its market value.

With changes in the market condition (e.g., changes in the demand for its products and in market prices), the firm revises its plans with respect to the above variables, and simultaneously, the firm's market value is revised. Initially, changes in the market value are mainly a response to changes in exogenous information. There is, however, a possible interaction between stock market variables and the firm's decisions. For example, the market may respond to "news" (formal announcement or leakage) about investment plans, while investment plans may respond to changes in the market value.[3]

The response of different variables to new information is inherently different. On the one hand, studies of investment suggest a built-in time lag between investment and new information. Parts of this time lag depend on the decision-making process in the corporation and on the lag between the "ordering of machines" and capital expenditures.

1. See Mansfield (this volume) for additional details and references.
2. For simplicity, we assume that the firm maximizes its market value. However, the same framework could be applied to other target functions.
3. An increase in the market value may reduce the cost of new equity capital.

On the other hand, studies of capital markets have suggested that market efficiency will lead to an instantaneous adjustment of the stock market to new information. If we could find an empirical variable that measures the flow of information to a firm, we could estimate the time patterns of response to such information. A comparison of the estimated time patterns may provide a clue to the structural relationship between the different variables. In this paper I look at the market value of the firm and its relationship to current and past measures of the firm's activity.

15.3 The Firm's Policy with Respect to Investment, R & D, and Patents

Economic theory suggests that R & D and investment are based on similar considerations, and that one could use the discounted present value of future income streams to evaluate the desirability of R & D investment. There are many differences between the two types of investment:

(a) The future net income stream resulting from an R & D project is subject to more uncertainty with respect to the cost of the R & D project and to the potential cash flows compared with an investment in plant and equipment. R & D projects are subject to major uncertainty about both the probability of their scientific success and the cost required for economically successful commercialization. Even a successful scientific completion (e.g., a patent) does not ensure business profit; not all patents result in the production of a new profitable product (see fig. 15.1). The risk of a given project is somewhat reduced by use of portfolios of R & D projects by big manufacturing firms.

(b) The uncertainty about an R & D project, as well as the business secrets involved in details of the project, may require the firm to rely more on internal financing (or financing by a single investor, e.g., the owner) rather than use the financial markets for borrowing. Thus, a firm's current earnings (net income inflow) may be a crucial source for financing an R & D project. This view is consistent with the casual observation that R & D projects normally represent a much smaller percentage of sales than does investment in fixed assets. (The accounting definition of R & D as current expense also encourages positive association between profits and R & D expenditures to stabilize accounting earnings.)

(c) Positive association between a firm's "success" and a change in R & D expenditures, viewed as an "extraordinary" expense, is also consistent with psychological experiments as well as "administrative" theories of a firm's behavior.[4] In other words, if we do not regard R & D as a "necessary" expenditure, but rather as a luxury item, then expendi-

4. I have benefited from discussion of this point with Professor Abraham Meshulach and Amos Tversky.

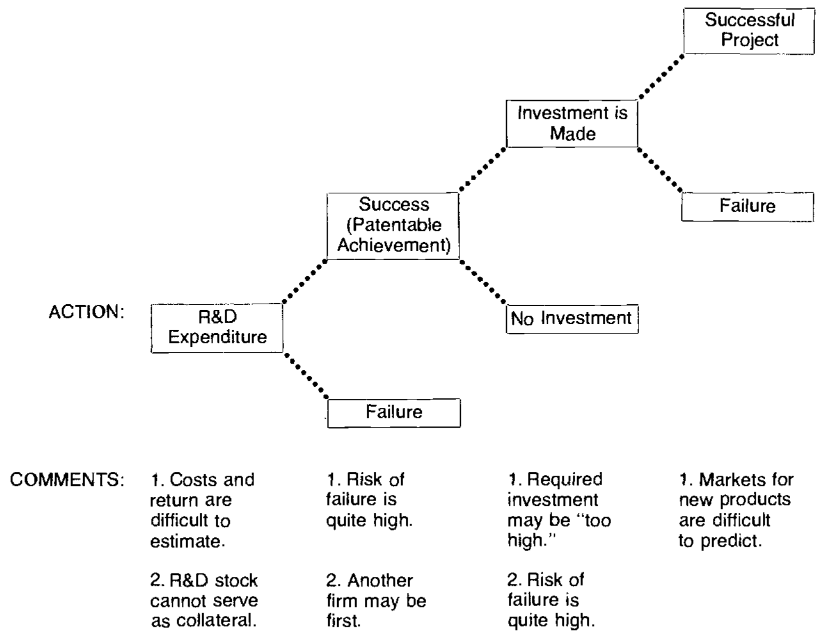

Fig. 15.1 R & D process and investment.

ture on R & D can be more easily justified in a period of comparable prosperity.

15.4 Patents

The patent variable is a random variable that measures the output of R & D activity (for a given "patenting policy"). The randomness of patents as a measure of inventive output results from several factors:

First, as mentioned by Pakes and Griliches (1980 and this volume), "There is a great deal of randomness in the timing of both the successful output of the R & D process and the decision as to when and whether to patent it."

Second, the value of a patent varies significantly between patents, and it is possible that a 100 percent increase in the number of patents by a firm is consistent with a decline in the real production of knowledge.

Since patents can be a proxy for an increase in technical knowledge, it is possible that a firm's patents are also relevant for other firms in the industry. First, patents by another firm may indicate a potential for new lines of research in the industries in which the firm operates.[5] Second,

5. In the same way that finding oil in a given area is positive information for other oil-seeking firms in the neighborhood.

patents may sometimes be imitated and improved at a fraction of the cost to the original inventor. Furthermore, patents by one firm may also create a new market which may affect the demand of current and new products by other firms. On the other hand, the effects of patents by other firms may also reduce the market value of a given firm, if the achievement of such patents reduces the firm's ability or increases its cost to obtain another patent.[6] It is possible that the net effects may be of different magnitudes and signs in different industries.

15.5 Framework for Empirical Work

The market value valuation approach, which was developed informally by Lester Telser, was applied in Ben-Zion (1972). This approach compares the market value of a firm to the value of its tangible and intangible assets. The tangible assets, which are a result of investment and net increase in assets, are represented by the value of common equity. The intangible assets are: a firm's "monopoly" power allowing it to obtain above normal return, the stock of R & D resulting from past R & D investments,[7] and a level of additional knowledge that may be partially reflected by patents.[8]

We can formalize this approach in the following equation, which relates the market value of a firm to its assets:[9]

$$\text{MV} = \alpha_1\text{BV} + \alpha_2\text{KM} + \alpha_3\text{KRD} + \alpha_4\text{KN}, \tag{1}$$

where BV is the book value of the firm; KM is a measure of the firm's monopoly power; KRD is a measure of the stock of R & D; and KN is a measure of the firm's patent-based stock of knowledge.

Since the stocks of the different kinds of intangible capital (KM, KRD, and KN) are not observed directly, we use the following approximations:

$$\text{KRD}_t = \sum_{k=0}^{\infty} \text{RD}_{t-k}(1-\delta)k = \beta_2\text{RD}_t, \tag{2}$$

where t denotes the current period, $t-k$ the past periods, and δ the rate of depreciation of R & D. The stock of R & D is thus viewed as a net value of past investment in R & D using a constant depreciation rate δ, but is in fact approximated by the current level of R & D, assuming a constant growth rate, with $\beta_2 = 1/[1-(g-\delta)]$, where g is the rate of growth of R & D in the past.

6. This will also depend on the effectiveness of the patent system in the industry and on the possibility of imitation.

7. Since R & D expenditure is regarded by accountants as current expenditure, the stock of R & D is not included in the book value of common equity.

8. We do not know in advance whether the stock of R & D summarizes all the accumulated knowledge in the firm, or whether patents—given R & D—supply additional information. This is an empirical question.

9. This framework is somewhat related to Tobin's q model.

We assume that the monopoly power KM is proportional to the "above normal" income of the firm:

$$\text{KM} = \beta_1(E + \text{R \& D} - \rho\text{BV} - \delta\text{KRD}) = \beta_1 E^*, \tag{3}$$

where ρ is the "normal" return to equity, and E is a measure of the firm's earnings. The term $E^*(= E + \text{R \& D} - \rho\text{BV} - \delta\text{KRD})$ is the above normal income of the firm. The R & D expenditures are added to earnings since accounting earnings (E) do not include R & D.

Finally, the capital value of patents for a given industry is assumed to be proportional to the number of patents of the firm (P) and the number of patents by the industry (PT):

$$\text{KN} = \beta_3 P + \beta_4 \text{PT}. \tag{4}$$

Substituting the above approximation in equation (1), we get:

$$\begin{aligned} \text{MV} = {} & \alpha_1\text{BV} + \alpha_2[\beta_1(E + \text{RD}) - \rho\text{BV}] \\ & + \alpha_3\beta_2(\text{RD}) + \alpha_4\beta_3 P + \alpha_4\beta_4\text{PT}. \end{aligned} \tag{5}$$

Assuming for simplicity that $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4$, equation (6) can be written as:

$$\text{MV} = \alpha_1\text{BV}\left[(1 - \rho) + \beta_1\frac{E^*}{\text{BV}} + \beta_2\frac{\text{RD}}{\text{BV}} + \beta_3\frac{P}{\text{BV}} + \beta_4\frac{\text{PT}}{\text{BV}}\right], \tag{6}$$

which can be approximated as:

$$\begin{aligned} \ln\text{MV} = {} & (\ln\alpha_1 - \rho) + \beta_0\ln\text{BV} + \beta_1\frac{E^*}{\text{BV}} + \beta_2\frac{\text{RD}}{\text{BV}} \\ & + \beta_3\frac{P}{\text{BV}} + \beta_4\frac{\text{PT}}{\text{BV}}, \end{aligned} \tag{7}$$

where β_0 is expected to be unity.

The empirical framework outlined above is also consistent with viewing current flows of R & D and patents as indicators of market opportunity. If a firm's manager takes on an R & D project, it indicates that he foresees an expansion of the market for the firm's products. In this interpretation the coefficient of current R & D will be positive, but it will not be necessarily related to the stock value of R & D capital but rather to future opportunities. While in principle one could distinguish between these two hypotheses, data limitations will not allow such a distinction.

A similar argument could be made for the inclusion of investment variables in the valuation framework. The inclusion of the investment rate in the market equation is also consistent with the Modigliani-Miller [1961] classical work, which suggests that if a firm has an opportunity to invest in a project with above normal returns, such investment opportunities increase the value of the firm. On the basis of the above, we can rewrite equation (7) as:

$$\text{(8)} \qquad \ln \mathrm{MV} = (\ln \alpha_1 - \rho) + \beta_0 \ln \mathrm{BV} + \beta_1 \frac{E^*}{\mathrm{BV}} + \beta_2 \frac{\mathrm{RD}}{\mathrm{BV}} + \beta_3 \frac{P}{\mathrm{BV}} + \beta_4 \frac{\mathrm{PR}}{\mathrm{BV}} + \beta_5 \frac{\mathrm{INV}}{\mathrm{BV}}.$$

Following the previous discussion, the current market value of a firm should incorporate expectation about R & D, patents, and investment variables. Assuming rational expectation, one could use future values of the above variable to approximate the predicted values.

We have not yet considered the effect of risk and leverage on a firm's market value. We use the "beta coefficient" as a measure of risk, even though some previous studies (e.g., Ben-Zion 1972) have shown that beta may not be a good measure of risk in a valuation framework. As to leverage, Modigliani and Miller (1963) have shown that it increases the value of a firm because of the tax advantage of debt in a world with a corporate income tax. Their results, however, are not unambiguous in the presence of a personal income tax, which treats interest income in a less favorable way compared to capital gains.

15.6 Data and Results

The data used in this empirical work consist of a sample of 157 industrial firms reporting R & D expenditures for the period 1955–77. This sample was constructed by Griliches and has been used extensively in other related work.[10] The empirical results reported here use a subsample of ninety-three firms for which we have continuous data series for all variables in the period 1969–77.[11]

The specific variables used in this study are based on Standard and Poor's Compustat tape and are the market value and book value of common equity and the earnings of each firm (after interest and taxes).[12] The beta risk measure used in this analysis is taken from the *Value Line Investment Survey* for 1977.

To treat the issue of leverage, we consider the basic market value equation for the firm as a whole (i.e., "unlevered" firm) as well as for the common equity part. The main difference between the two versions is that for the common equity version, the market value, book value, and

10. See Pakes and Griliches (this volume) for a more detailed description of this sample.
11. This sample is closely related to the sample used in Mairesse and Siu (this volume).
12. The market value of each firm is divided by Standard and Poor's Stock Price Index (S & P 425) to take into account the effect of the market trend.

earnings are calculated from the point of view of the firm's stockholders (which is the standard accounting and financial treatment), in the whole firm approach we have considered the market value of bonds, preferred stocks, and common stocks. The book value is the current value of the firm's assets, while earnings are measured as net operating income before interest and taxes. (See Griliches 1981 for details of this approach.)

In the empirical framework we also consider two approaches to test the effect of the industry patents. First, as summarized by equation (8), we consider the patents by other firms in the industry as a possible addition to the given firm's stock of knowledge in the same way as the firm's own patents. In this approach, patents by other firms in the industry have stronger relative effects on the market value of the smaller firms in the industry. As an alternative empirical approach, we can measure the effect of other own patents as a ratio of patents to book value of the other firms in the industry, or the "patent intensity" of the industry. The use of the patent intensity variable can be justified on two counts:

(a) A firm's ability to benefit from patents and knowledge created by other firms in the same industry may depend on its relative size. The size of a firm may restrict its ability to imitate and utilize in production the patents developed by other firms in the same industry. Furthermore, if the industry definition is quite wide (two- or three-digit SIC), a firm's relative size may be a proxy for the percentage of industry products in which the given firm is actually involved.

(b) The overall industry patent intensity may affect a firm indirectly as a proxy for the potential increase in the markets for the industry's product, from which firms may benefit whether or not they currently have patents.

The alternative approach to industry patents is summarized by:

$$\ln \mathrm{MV} = \alpha_0 + \beta_0 \ln \mathrm{BV} + \beta_1\left(\frac{E}{\mathrm{BV}}\right) + \beta_2\left(\frac{\mathrm{RD}}{\mathrm{BV}}\right) + \beta_3\left(\frac{P}{\mathrm{BV}}\right) + \beta_4\left(\frac{\mathrm{PT}}{\mathrm{TBV}}\right) + \beta_5\left(\frac{\mathrm{INV}}{\mathrm{BV}}\right) + \beta_6 \cdot \mathrm{beta}, \tag{9}$$

where the ratio (PT/TBV) represents the patent intensity of other firms in the industry, and beta represents a measure of risk.

15.7 Empirical Results

The specific variables used in this study are as follows: In the common equity version, market value and book value of common equity as well as net earnings (available to common) and net investment are taken from the Compustat data tape. R & D expenditures and "patents applied for" were collected (and constructed) by Griliches. For the beta risk measure we have used the *Value Line Investment Survey* for 1977. (A value of one was assigned to missing beta values.) The market value of each firm was divided by Standard and Poor's Stock Price Index (S & P 425; 1959 = 100) to take into account the trend of the overall market. Industry classification for ten industry groups is based on the work of Griliches and Mairesse (this volume).

For the whole firm version we use the market value of all the firm's securities (bonds, preferred stocks, and common stocks). The book value variable reflects the value of all assets evaluated at current prices. These two variables were constructed by Griliches (1981). As the earnings variable, we use the net operating income from the Compustat tape, which is a measure of gross income of the firm and includes net earnings, preferred dividends, interest payment, operating expenses, and taxes. Other similar firm variables in the common equity version are R & D expenditures, investment, and patents.

Because of some randomness in the timing of patents, we use a two-year moving average of their annual numbers. The limited time span of patent data availability and the reporting of patent applications only on their approval restrict our sample period to the years 1969–76. We also use industry dummy variables to control for differences between industries.

The results for the common equity version (for the period 1969–76) are given in table 15.1, while the results for the whole firm version are given in table 15.2. The results indicate that—given the book value—earnings, investment, and R & D are important determinants of the market value for both the common equity and the firms as a whole. These results seem to support the simple theoretical framework developed in this paper.

Patents seem to have significant positive effects (as expected) only in the industry totals version. The effect of a firm's patents on its market value is positive but not statistically significant. The weak effect of a firm's own patent numbers may result because the market does not normally know at the time of application whether a patent applied for will in fact be approved. In this respect the variable we use to measure the "perceived" number of patents is subject to error. This error may be less important in the aggregate industry data.[13]

The effect of industry patents on the market value of individual firms seems to be quite high, which may indicate that patents are proxies for other omitted variables (e.g., expected market growth). To arrive at a meaningful estimate of the magnitude of such effects, we will have to estimate separate equations for each industry.

13. The results reported here are for the "patent intensity" variable, that is, industry patents/industry book value. Results of the alternative version, industry patents/firm book value, are less significant.

Table 15.1 **Determinants of the Market Value of the Firm's Common Equity, 1969–76 (regression includes also industry dummies)**

Variable	Coefficient[a]	Variable	Coefficient[a]
ln BV	1.012	*P*/BV	0.166
	(61.7)		(1.60)
RD/BV	0.654	TP/TPB	5.244
	(1.8)		(10.70)
INV/BV	0.409	Beta	0.226
	(1.6)		(1.67)
EAR/BV	2.119	R^2	0.9272
	(8.4)	N	727

[a]*t*-values are given in parentheses.

Table 15.2 **Determinants of the Market Value of the Firm, 1969–76 (regression includes also industry dummies)**

Variable	Coefficient[a]	Variable	Coefficient[a]
ln BV	1.027	*P*/BV	0.065
	(88.9)		(0.8)
RD/BV	3.376	TP/TPB	4.673
	(8.7)		(11.4)
INV/BV	2.623	R^2	0.955
	(7.3)	N	728
EAR/BV	2.143		
	(14.30)		

[a]*t*-values are given in parentheses.

Looking at the size of the coefficient of earnings, an increase in current earnings of one dollar makes the same impact on the market value as a two-dollar increase in the book value.[14] This indicates that an increase in current earnings also affects the market's expectation about future earnings.

The results in table 15.2 indicate that a one-dollar expenditure in R & D or investment increases the firm's market value by a magnitude of 2.6 or 3.3, respectively, relative to the market's valuation of one dollar of its current book value. The results for the common equity version in table 15.1 indicate that the effects of R & D expenditure and investment are much smaller. A one-dollar expenditure on R & D or investment is equivalent to a 0.6 or 0.4 increase in the book value, respectively.[15] When we do not include earnings in the equation, the R & D coefficient is much

14. Because of the use of different dependent and independent variables, the two versions are not strictly comparable.

15. As noted before, these results cannot be compared in a simple way because of different definitions of variables in the two versions.

higher, indicating that some of the effects of R & D are captured by the firm's earnings.

In evaluating these results, one should note, however, that they are based on a relatively small number of firms in very different industries. We would like to delay any concrete conclusions until we have estimated these models using a new larger sample, where we shall be able to have better control for differences between industries. The current findings are not very stable, the magnitude of the estimated coefficients varying significantly with changes in estimation techniques or the exact specification of the equation. The main qualitative conclusions, however, are quite robust. In particular, it is interesting that the results are similar when we use the future values of these variables (in a two-stage least-squares framework, not reported here).

On the basis of the finding that patents by other firms in the industry affect the market value of the firm, we also tried to test the effect of R & D and investment expenditures by other firms. The results indicate that R & D investment expenditures by other firms do not have a significant effect on a firm's own market value.

Finally, to test a dynamic version of our model, we have considered a first difference version of the basic equation for common equity. In this approach we relate the change in the market value to changes in R & D, investment, earnings, and patents. The theory of efficient financial markets assumes that the current price incorporates expectations of the future values of the relevant variable. Thus, one would expect that only the unexpected part should be related to the change in prices.[16]

The theory of the capital asset pricing model (CAPM), developed by the works of Sharpe (1964) and Lintner (1965), emphasized that the return on an individual security is related to the overall market return.

$$R_i = \alpha_i + \beta_i R_M + u_i, \tag{10}$$

where R_i is the return on the individual security, β_i is the beta risk measure, and R_M is the return on the market portfolio, for which we use Standard and Poor's Stock Price Index (S & P 425). In the dynamic version, we have combined this approach by regressing the return on common equity on the general market return and the percentage change in the firm's earnings, R & D, and investment during that year.

To combine cross-section and time-series data, we have multiplied the observed market return by the firm-specific beta risk measure. We have estimated the following equation:

$$R_i = \gamma_0 + \gamma_1(\beta_i R_M) + \gamma_2\left(\frac{\Delta E}{E}\right) + \gamma_3\left(\frac{\Delta \mathrm{RD}}{\mathrm{RD}}\right) + \gamma_4\left(\frac{\Delta \mathrm{INV}}{\mathrm{INV}}\right), \tag{11}$$

16. For a similar approach, see Griliches (1981) and Ben-Zion and Rozenfeld (1979).

Table 15.3 **The Effect of Changes in the Earnings, R & D, and Investment on the Company Rate of Return, 1967–76**

Variables	Coefficients in Actual Version[a]	Coefficients in Unexpected Version[a]
DE	0.938	1.357
	(7.8)	(10.2)
DRD	−0.402	0.097
	(2.0)	(1.9)
DINV	0.219	0.001
	(1.5)	(0.0)
Beta	1.17	1.17
	(4.3)	(25.0)
R^2	0.407	0.434
DF	914	914

[a] *t*-values are given in parentheses.

where we have considered (alternatively) actual changes and unexpected changes. The unexpected change ("surprise" in Griliches 1981 terminology) is obtained by subtracting a predicted change based on past data from the overall change.[17]

Results for 1967–76 are presented in table 15.3. They suggest that changes in earnings are significant in explaining market returns (either actual changes or expected changes). The unexpected components of R & D are also significant in explaining market returns. Unexpected investment seems to be less important. It is important to note that our predicted values for earnings, R & D, and investment are based solely on published data from previous annual reports (balance sheet and income statement) as reported in the Compustat tape. Stock market investors, particularly financial analysts and managers of large portfolios (mutual funds, pensions funds), are better informed. At any point in time an analyst's prediction for each of the above variables is based on additional information and should outperform our technical predictions.[18] It thus seems that if we could use the true (unobserved) predictions by investors, results would be much sharper.

15.8 Concluding Comments

The results in this paper suggest the market value of a firm is affected by its R & D and investment policy. The patent intensity of the industry as

17. To calculate the predicted value in each equation, we have regressed the current rate of change in each variable on lagged value of changes in the variable as well as on changes in sales. This procedure should be viewed as an illustration rather than a complete model of prediction.

18. For a study supporting this claim, see Brown and Rozeff (1978).

a whole has a positive effect on a firm's market value, while the effect of a firm's own patents is weaker. The results also support the common notion that earnings are probably the most important factor in the market value equation for both levels and rates of change. A more detailed analysis (by industry groups) could yield sharper results and would increase our understanding of the determinants of market value.

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Comment Robert E. Evenson

Professor Ben-Zion reports estimates of the effects of R & D investment, other capital investment, and patenting on the market value of the firm. He finds support for the hypothesis that R & D investment produces an increase in the market value of the firm. Its effect appears to be slightly larger than the effect of capital investment. Perhaps the most interesting finding in the paper is that the patent intensity of other firms in the same industry affects the market value of the firm. While this finding is open to a range of interpretations, it represents at least a potential recognition of some of the factors influencing the productivity of R & D investment.

A number of the papers in this volume have treated invention in a very restricted way. The probability that invention by a particular firm conducting R & D is altered by the inventions of other firms, the scientific and technological discoveries of public research centers, or the acquisition of scientific human capital by the firm is often not considered in these studies. Nor is R & D investment by competing firms, which is likely to produce inventions and patents that will block certain lines of invention and cause diversionary or "inventing around" R & D strategies, taken into account. Samples of large firms (as in the case of Ben-Zion's sample of ninety-three large firms) can also provide a very biased picture of the industry equilibrium. Smaller firms in the industry are likely to have different levels of R & D spending and different R & D strategies. They may be purchasing technology through licensing arrangements and engaging in more adaptive or derivative invention than large firms.

Ben-Zion's paper at least considers some of these factors and justifies the inclusion of the industry patent variable on the grounds that patents

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by another firm "may sometimes be imitated and improved at a fraction of the cost to the original inventor." This perspective is consistent with the legal scholars' perception of the bargain inherent in the patent laws. In return for the grant of a limited monopoly, the inventor is required to remove from secrecy the essentials of his invention by adequately disclosing them in the patent document. This disclosure is deemed to be of value to society for the reasons given by Ben-Zion.

Ben-Zion also notes that patents by other firms have a blocking effect, lowering the value of the firm's own R & D by forcing more diversionary R & D to invent around the other firms' patents. The patent intensity of other firms may also index a more general industry effect. Industries which are technologically dynamic will tend to have high patent/book value ratios and high market value/book value and market value/earnings ratios. Of course, if the market is valuing all firms in the industry relatively highly regardless of their own patenting, it is presumably expecting strong disclosure effects. These disclosure effects may not induce patented inventions but could induce imitations and minor unpatented inventions.

Ben-Zion's obtaining own R & D effects but not own patenting effects on market value is consistent with the notion that firms can take advantage of disclosure effects by investing in R & D but that this R & D may not lead to patenting inventions. The industry equilibrium (and Ben-Zion's sample) may well include firms with a heavily adaptive, imitative R & D strategy along with firms with a more pioneering invention strategy. The definition of the industry variable as the patent intensity of the firms seems appropriate. It is a bit puzzling that the counterpart R & D intensity of other firms was not significant. It appears that patents per unit of R & D vary significantly across industries, calling into question their treatment as a common metric of real invention. If patents in a given industry tend to be relatively "small," that is, have few claims, a given R & D investment in that industry will produce more patents than investment in an alternative industry but not necessarily more real invention. R & D intensity should then be the better measure of real invention.

If one is to pursue this line of analysis further, one would wish to consider patenting in the industry by foreigners as well as by U.S. firms. Ed Mansfield's work on R & D by overseas affiliates of U.S. firms demonstrates that much of this R & D produces transferable technology, presumably with strong disclosure effects as well. This extension would require more attention to the blocking or competitive effects of patenting. Other measures of patent quality are now available as well. One can obtain data on subsequent citations of a given patent, which would be a meaningful quality weight for older patents. One can also obtain data on the granting of patent protection in other countries based on any U.S. patent.

Ben-Zion's paper has the merit of both being quite readable and not providing unnecessary algebra. His results generally fit well in the market value framework utilized, and this appears to be a useful methodology for investigating the questions posed. The model appears to be more restricted than necessary in some respects. I would think that with data on R & D from 1955–1977 it would not be necessary to approximate KRD_t, as in equation (2), by assuming a constant growth rate. It also isn't clear why a two-year average of patents is used. I would have thought that this variable should be in a "stock" form, as is R & D. Ben-Zion notes that the market test of the real value of invention requires time (even though the stock market forms expectations instantaneously). The use of the term "patent applications" is also misleading, since the patents have actually been granted.

Ben-Zion offers a dynamic version of the model which he regards as supportive of the model. He does not provide a rationale for excluding patenting from the dynamic version, even though the patented invention has a natural interpretation in the context of unexpected or surprise events. As he notes, further detailed analysis is required to clarify a number of unanswered questions. Given the findings of this paper, one can say that further analysis along these lines has promise.