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12 Patents, R & D, and the Stock Market Rate of Return: A Summary of Some Empirical Results

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This is an abstract of the results obtained in an earlier paper (Pakes 1981). That paper was motivated by the recent computerization of the U.S. Patent Office's data base. This has provided us with perhaps the most direct, and certainly the most detailed, indicator of inventive activity currently available. These data, then, ought to enable us to perform more detailed investigations of the causes and effects of invention and innovation than have been possible to date. To use the patent data effectively, however, requires an empirical understanding of the relationship between successful patent applications and measures of the inputs to, and the outputs from, the inventive process.

The study summarized here is designed to investigate the dynamic relationships between the number of successful patent applications of firms, a measure of the firm's investment in inventive activity (its R & D expenditures), and a measure of firm performance (its stock market values). There is a particular reason for using stock market values as the performance indicator in this context. As noted by Arrow (1962), the public-good characteristics of inventive output make it extremely difficult to market. Returns to innovation are mostly earned by embodying it in a tangible good or service which is then sold or traded for other information that can be so embodied (Wilson 1975; von Hippel 1982). There are, therefore, no direct measures of the value of invention, while indirect measures of current benefits (such as profits or productivity) are likely to react to the output of the firm's research laboratories only slowly and erratically. On the other hand, under simplifying assumptions, changes in the stock market value of the firm should reflect (possibly with error) changes in the expected discounted present value of the firm's entire,

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uncertain, net cash flow. Thus, if an event does occur that causes the market to reevaluate the accumulated output of the firm's research laboratories, its full effect on stock market values ought to be recorded immediately. This is, of course, the expected effect of the event on future net cash flows and need not be equal to the effect which actually materializes. Measuring expectations rather than realizations has its advantages. In particular, expectations ought to determine research demand, so the use of stock market values will allow us to check whether the interpretation we give to our parameter estimates is consistent with the observed behavior of the research expenditure series.

This study is organized around a model serving both to interpret the parameters estimated and to provide a set of testable restrictions which indicate whether this interpretation is consistent with the observed behavior of the data. Two behavioral assumptions underlie the model (see Lucas and Prescott 1971 for a more detailed discussion of their theoretical implications). First, the firm is assumed to choose a research program to maximize the expected discounted value of its future net cash flows. A research program is defined as a sequence of random variables determining the firms current and future research expenditures conditional on (or as a function of) the information that will be available to the firm when those research expenditures must be made. The program is modified yearly on the basis of information accumulated on: the success and failure of the firm's R & D program; conditions in the markets relevant to the output of the firm's R & D activities; and input prices. The second behavioral assumption of the model determines the formation of stock market values. The stock market value of the firm is assumed to be an error-ridden measure of the expected discounted value of the firms future net cash flows. This assumption provides the interrelationship between the forces that drive the R & D expenditure series and those that drive stock market values, and it implies certain restrictions on the behavior of the data.

To be more precise, one can show that if the stock market provided an exact evaluation of the expected discounted value of the firm's future net cash flows based on the same information set used by management, then the one-period excess rate of return on the firm's equity (capital gains plus dividends on $1 invested in the firm minus the interest rate) would equal the percentage change in the expected discounted value of future net cash flows caused by the information accumulated over the given period. We are assuming that the observed rate of return on the firm's equity equals this change plus a disturbance uncorrelated with information publicly available at the beginning of the period. The latter assumption ensures that the process generating this disturbance does not allow agents operating on the stock market to use publicly available information and a simple linear trading rule to make excess returns on that market.

To the equations that determine the one-period rate of return and research demand, an equation is added that determines patent applications. Patents are assumed to react to the same events that cause revisions in the firm's R & D program and changes in the market's evaluation of that program, and, in addition, to be subject to a separate disturbance process. The disturbance process in the patent equation reflects differences in what Scherer (1965a; 1965b) has termed the propensity to patent; that is, it reflects differences in the number of patents applied for given the history of the inputs (the firm's current and past R & D expenditures) and the outputs (the firm's current and past stock market values) of the firm's inventive activity. This disturbance is allowed to be freely correlated over time but has the distinguishing characteristic that changes in it never affect the firm's R & D program or its stock market value. This provides an additional set of testable restrictions and underlies the interpretation of the variance in the disturbance process as differences in the propensity to patent.

The econometric structure of the model is that of a dynamic factor analysis (or index) model (see Geweke 1977 or Sargent and Sims 1977). There are three equations: one for each of the three observed variables (the stock market rate of return, R & D expenditures, and patent applications). The dynamic factor is a stochastic process affecting all three variables, though the time pattern of this factor's effect on the different variables differs. This factor is built up from current and past events that have caused changes in the expected discounted value of the firm's formal inventive endeavors. In addition to the dynamic factor, the patent and stock market rate of return equations are affected by the disturbance processes outlined above. It can be shown that, if these assumptions provide an adequate description of the data, the trivariate stochastic, process generating patents, R & D, and the stock market rate of return have a particularly simple recursive form in which all the restrictions of the model appear in the form of exclusion restrictions. This makes the recursive form particularly simple to estimate and interpret.

The parameters estimated from the recursive form can be used to calculate: the change in the stock market value of the firm associated, on average, with given changes in patent applications and in R & D expenditures; the change in R & D expenditures associated with given changes in patent applications; the time pattern of the effect of events changing the stock market value of the firm's inventive endeavors on patent applications and on R & D expenditures; the percentage of the variance in the stock market rate of return attributable to the factors causing changes in the firm's inventive activity; the percentage of the variance in the patent variable that is caused by differences in the propensity to patent (i.e., that never affects either stock market values or the firm's R & D program); and the serial correlation properties of this propensity in a given firm over time.

Before going on to a brief description of the empirical results, it is worth elaborating on the implications of two of the restrictions that were imposed. Neither of these restrictions were necessary. Rather, both were maintained because the data could not distinguish between the simpler models they implied and the more complicated models that would result without imposing them. First, no distinction was made at this stage between the different kinds of events likely to cause changes in inventive activity (say demand shocks versus supply shocks, where demand shocks are only transformed into more patents as a result of the R & D expenditures they induce, while supply shocks have a direct effect on patenting as well as an indirect effect via induced R & D activity). In principle, the techniques and data used here should be sufficient to isolate the effect of these different events. The data indicated, however, that to accomplish this task empirically one is likely to require a measure that distinguishes more effectively between demand and supply shocks than R & D does (perhaps investment expenditures). This is a topic I intend to pursue further. Second, in the model estimated, no allowance was made for a disturbance process in the R & D demand equation; that is, a process that does affect R & D but does not affect either the stock market value of the firm or its patent applications. Here the data indicated that such a process was simply not necessary. This was comforting since it indicates that once we move away from indirect measures of current benefits (such as productivity) there is less need to worry about measurement error in the R & D series.

The data set used to estimate the model contained patent applications, R & D expenditures, and stock market rates of return for 120 firms over an eight-year period (this data set is described more fully in Pakes and Giliches, chap. 3 in this volume). The restrictions of the model were accepted, and, on the whole, parameters were estimated with a great deal of precision. The qualitative nature of the empirical results can be summarized quite succinctly. First, it is clear that there is a highly significant correlation between the stock market rate of return and unexpected changes in both patent applications and R & D expenditures (unexpected changes here refer to changes that could not be predicted from the history of the variables in our data set). Moreover, the estimates imply that the unexpected changes in the patent and R & D series are associated with quite large movements in stock market values. On the other hand, the estimates imply that the vast majority of the variance in the stock market rate of return is determined by factors that have little to do with inventive activity. Thus, if one were to use movements in the stock market rate of return as an indicator of changes in the private value of inventive output (and there are strong theoretical and empirical reasons for doing so), one ought to be careful to allow for a disturbance process to intercede between them (as noted above, we do have information on the properties of that disturbance process).

The events that do cause the market to reevaluate the firm's inventive endeavors have long-lasting effects on both the patents and the R & D expenditure series of the firm. In fact, most of the cross-sectional variance in patents is caused by them; that is, differences in patent applications between firms seem to be mostly determined by the same factors which cause differences in the market's evaluation of the firm's inventive endeavors. On the other hand, most of the variance in patent applications within a given firm over time is determined by intertemporal differences in the propensity to patent; that is, by factors that never cause changes in its R & D program or its market value. As a result, the patent variable is likely to be less useful in studies of changes occurring in the inventive output of a given firm over time. This last statement must be modified somewhat when one considers longer term differences in the patents applied for by a given firm (say differences over a five- or a ten-year interval), since a larger proportion of their variance is caused by events that lead the market to reevaluate the firm's inventive output during these periods.

The timing of the impact of the events that cause unexpected changes in the market value of a firm's inventive activity on patents is very close to the timing of their impact on R & D. In fact, one gets the impression from the estimates that an event which causes a 1 percent change in the market value of a firm's inventive activity starts a chain reaction leading to more R & D expenditures far into the future, with the firm patenting around the links of the chain almost as quickly as they are completed. Thus, if one were to use the estimates to compute a distributed lag from R & D to patents, most of the weight in the lag coefficients would be concentrated in the first three R & D variables. This lag distribution also has a long slim tail which probably represents the effect of the basic research done in the past on current patented innovations. Finally, these timing patterns imply that current patent applications are highly correlated with the factors setting current R & D demand.

To date our understanding of the role of invention and innovation in economic processes has been severely hampered by a lack of empirical evidence on its causes and its effects. In large part this reflects the difficulty in finding (or constructing) meaningful measures of invention. This paper investigated whether (and in which dimensions) the patent data are likely to alleviate this problem. The answers are somewhat mixed. There is a large variance in the patent applications of different firms, and this variance is mostly determined by events that have changed both the market value of the firm's research program and its research input. Though, in the cross-sectional dimension, differences in current patent applications are closely related to differences in current research investments, both of these variables have long memories; that is their levels reflect events that have occurred over a long time period. In several situations R & D (and, for that matter, market value) data are simply not available (of particular interest is when one wants to study the research investments of different firms in particular product fields). Use of the patent data as a proxy for R & D in these cases, together with some of the qualitative results derived here, is likely to be quite fruitful. On the other hand, much of the variance in the patent applications of a given firm over time is simply a result of noise (differences in the propensity to patent). Of course, some information is still in the time-series dimension. If one were to observe, for example, a sudden burst in the patent applications of a given firm, one would be quite sure that events have occurred causing significant change in the market value of its R & D program, but smaller changes in the patents of a given firm are not likely to be very informative. To establish that one can use the patent and R & D data together to distinguish between the different kinds of events that can cause changes in research activity, one requires the addition of more variables, and perhaps more structure, to the model used here.

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