Inter-firm technology flows and productivity growth

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Abstract:

Technologies enter a firm as the result of its own R&D activity and through such channels as the licensing of others' technologies or the purchasing of never vintages of capital. The empirical evidences reported here suggests that both sources are important factors influencing a firm's productivity growth.

Keywords: R and D | technology advancement | productivity growth

Article:[*]

1. Introduction

Researchers have investigated the relationship between R&D and productivity growth for nearly 20 years; however, the topic has recently acquired renewed importance among those seeking to quantify the determinants of the post-1965 decline in U.S. productivity. Generally, a correlation has been sought, using cross-sectional data, between an index of productivity growth and past R&D intensity. Most studies conclude that a firm's (industry's) R&D, a proxy for technological advancement, is significantly related to its growth in productivity.

These inquiries have been useful, but are somewhat limited in scope; for the technological basis of a firm is broader than the activities of its own R&D program. Technologies can enter a firm not only as the result of its own R&D – we call these induced innovations – but also through such channels as the licensing of others' technologies or the purchasing of new capital equipment that embodies new technologies (perhaps the result of the capital supplier's R&D) – we call these purchased innovations. Surprisingly, few efforts have been made within the productivity literature to account for this inter-firm flow of technology. The quantitative evidence that is available comes from Terleckyj (1974, 1980, 1982) and Scherer (1981a, b) and is based on aggregated industry data. Both conclude that R&D technologies embodied in capital or

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intermediate goods purchases have a greater impact on an industry's productivity than R&D conducted within the industry.

The purpose of this note is to quantify the separate impacts of induced and purchased innovations on measured productivity growth using firm specific data. The model, data, and empirical findings are presented in section 2, and some concluding remarks are offered in section 3.

2. The analytical framework

2.1. The model

The analytical model underlying previous R&D-related productivity studies assumes a three-factor Cobb-Douglas production function written in terms of output (Y), labor (L), physical capital (K), and technical capital (T):

$$Y = A_0 e^{\lambda t} L^{\beta} K^{(1-\beta)} T^{\alpha}, \tag{1}$$

where A_0 is a constant, λ is a disembodied rate of growth parameter, t represents time, and β and α are output elasticities.[1] Constant returns to scale are assumed only with respect to L and K. Differentiating eq. (1) with respect to time and defining total factor productivity, ρ, as a Solow-type of residual leads to

$$\rho = \lambda + \phi(I_T/Y), \tag{2}$$

where $\phi = (\partial Y/\partial T)$ is interpreted to be the marginal product of technical capital, and $I_T = \partial T/\partial t$ represents the net investment of the firm into that stock.

Stochastic versions of eq. (2) have traditionally been estimated across industries or firms using the industry's or firm's total R&D expenditures to approximate I_T. Here, I_T is conceptualized in several ways. First, it will be measured conventionally as the firm's total, self-financed R&D expenditures, RD. Second, I_T will be represented by a proxy measure of the firm's total expenditures on technological advancements, *TECHADV*. And, third, I_T will be measured by disaggregating *TECHADV* into the dollar value of induced (self-financed) technologies, *RD,* and the dollar value of inter-firm purchased technologies, *PURCH*(= *TECHADV* – *RD*).

2.2. The data set

Versions of eq. (2) are estimated using data for 302 U.S. manufacturing firms (discussed below). Total factor productivity, p, is measured as the growth rate in residually-calculated productivity between 1975 and 1979. First, a productivity index, $g_t = \ln Y_t - b \ \ln L_t - (1-b) \ \ln K_t)$, was calculated for each firm, t = 1975-1979. The principle data source for these calculations was

[1] For a critical discussion of this model see, for example, Griliches (1979).

Compustat.[2] Then ρ was measured as the slope coefficient from a regression of g_t on trend for each firm [Mansfield (1980), Link (1981)].

Each firm's own R&D expenditures, *RD,* were measured as total 1977 R&D dollars as reported by Compustat.

Data related to each firm's total expenditures on technological advances are not available; however, a rough indicator of *TECHADV* was calculated based on the assumption that the percentage of a firm's technological advances generated through its own R&D activity, *INDUCE,* approximates the ratio of its R&D expenditures to its total expenditures on technological advances: *INDUCE = RD/TECHADV.* Survey data were gathered from 302 major R&D firms within the manufacturing sector in an attempt to quantify the dichotomy between the use of a firm's own R&D resources relative to the use of existing external technology markets. Specifically, data were collected on the percentage of a firm's technological advances that are induced through its own self-financed R&D activities, *INDUCE.* These values reflect the firm's 1976 subjective evaluation (as reported by the R&D vice president) of the role of its R&D program within its overall strategy for acquiring new technologies.[3] Accordingly, *TECHADV= RD/INDUCE.*

Finally, given each firm's estimate of its total expenditures for technological advances, the dollar value of purchased, as opposed to own R&D based, technologies was calculated as *PURCH* = (*TECHADV- RD*).

Following Kendrick (1973), and others, an index of industry unionization, *U,* is also included in the estimating version of eq. (2).[4]

2.3. The empirical results

[2] Output was measured as net sales, defined as gross sales and other operating revenue less discounts, returns, and allowances, deflated by the industry specific producer price index in the Bureau of Labor Statistics. Labor, *L,* was represented by the total number of employees as reported by each firm to its stockholders. Physical capital, *K,* was approximated by the value of gross plant, representing tangible fixed property such as land, building, and equipment, deflated by the implicit price index for non-residential gross private investments of the Bureau of Economic Analysis. The average share of labor in total sales, *b,* over the period 1975-1979 was estimated as the total labor expenditures of the firm in 1977 per unit of 1977 sales. For firms not reporting labor-related expenditures to Compustat. labor's share was computed using the product of the average 1977 annual wage in each firm's industry as reported by the Bureau of the Census. and the total number of 1977 employees in the firm. The average share of capital is $(1 - b)$.

[3] The survey population was 329 firms; however, complete Compustat data on 27 of the smaller firms were not available. These remaining 302 firms accounted for 69.3 percent of total 1977 net sales in manufacturing and 73.6 percent of total 1977 private R&D in manufacturing. The range of reported values on *INDUCE* is 0.12 to 0.83 with a standard deviation of 0.27. The mean is 0.46. A more detailed description of these data is in Link. Tassey and Zmud (l983).

[4] Kendrick (1973) suggests that the impact of unionization on productivity is ambiguous. On the one hand, work rules or efforts to thwart innovation by some unions could lower productivity if employment levels are threatened. On the other hand, if wages are significantly higher in certain unionized industries, firms may induce labor saving technologies that could raise measured productivity. Most researchers have found the net effect to be negative. *U* is the percentage of workers unionized in the three-digit industry in which the firm performs its main operations [Freeman and Medoff (1976)].

The least-squares results, with t-statistics in parentheses, are reported in table 1. The results in column (1) compare favorably with the results of other researchers.[5] The estimated coefficient on the R&D variable is positive, but not significantly different from zero. However, when the firm's investment into the stock of technical capital is approximated by *TECHADV,* the associated coefficient [column (2)] is noticeably larger and is significant at the 0.05 level. Perhaps the most interesting findings are reported in column (3). The estimated coefficient on the purchased R&D variable, *PURCH,* is positive and significant at the 0.01 level or better and the significance on the *RD* term reaches 0.05.

From these results it appears that *both* sources of a firm's technological advances are important determinants of its productivity growth and that purchased technologies have the relatively greater and more significant impact. This conclusion complements the aggregate results of both Terleckyj and Scherer.

Table 1. Estimated regression results: n = 302 (t-statistics in parentheses)

Independent variables	**(1)**	**(2)**	**(3)**
Constant	0.063 (3.92)[a]	–0.266 (–2.36)[b]	–0.374 (–2.75)[c]
RD/Y	0.063 (1.49)		0.047 (2.13)[b]
TECHADV/Y		0.118 (2.32)[b]	
PURCH/Y			0.247 (3.02)[c]
UNION	–0.008 (–1.81)[a]	–0.007 (–1.61)[a]	–0.007 (–1.68)[a]
R^2	0.34	0.41	0.49

[a] Significant at the 0.10 level.
[b] Significant at the 0.05 level.
[c] Significant at the 0.01 level or better.

3. Concluding remarks

The main finding of this study is that the composition of a firm's total expenditures for technological advances is an important factor related to its productivity growth. Although this idea is not new, the findings presented here are the first to quantify the importance of technology flows on productivity growth at the firm level. Thus, previous studies examining only in-house R&D as a proxy for innovative activity are perhaps limited in their generalizability.

Still, it is very important to emphasize that these findings are preliminary and perhaps not without error. The key variable in this study reflects individuals' subjective evaluation about their firm's overall innovative activities, and is thus quite noisy. Nevertheless, it is hoped that this experiment will suggest to other researchers a quantitative method for thinking about the entire sphere of a firm's technological sources rather than strictly focusing on its R&D behavior.

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