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The lag structure of the relationship between patenting and internal R&D revisited

Ning Wang[a,1], John Hagedoorn[b,c,*]

[a] Department of Organization and Strategy, Maastricht University, The Netherlands
[b] Department of Organization and Strategy and UNU-MERIT, Maastricht University, The Netherlands
[c] Department of Management, Royal Holloway, University of London, Egham, Surrey, United Kingdom

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ABSTRACT

The principal purpose of this study is to revisit the classic research question regarding the lag structure of the patents–R&D relationship through an examination of the impact of internal R&D on firm patenting in the context of the global pharmaceutical industry during 1986–2000. Our empirical analysis, using both a multiplicative distributed lag model and a dynamic linear feedback model, differs from previous work that examines the patents–R&D relationship in three aspects. First, our estimation results exhibit direct evidence on lagged R&D effects, with the first lag $(t-1)$ of R&D being significant in all distributed lag specifications. Second, a U-shaped lag structure of the patents–R&D relationship is found in most estimations of the multiplicative distributed lag model, which suggests a potential long-run effect of internal R&D investments on firm patenting. Finally, the results from the dynamic linear feedback model coincide with those from the multiplicative distributed lag model, indicating not only lag effects from more recent R&D but also an overall long-run effect of internal R&D investments in the distant past on the knowledge production or innovation process of incumbent pharmaceutical firms.

1. Introduction

In the attempt to learn about gestation lags in knowledge production of in-house research and development (R&D) by firms, researchers have repeatedly examined the relationship between R&D expenditures and patents, which are taken as an output indicator of R&D (Bound et al., 1984; Griliches, 1990).[2] The question of interest is the lag structure of the patents–R&D relationship, studied by considering the number of patents applied for and received by firms as a function of their current and lagged R&D expenditures.

Pakes and Griliches (1984a) is probably the first attempt to look at the time shape of the distributed lag between patenting and internal R&D activity of firms. In their panel-data model (with a log-log functional form), Pakes and Griliches (1984a) found evidence of a lag truncation effect in the distributed lag of R&D on patents. The estimated coefficient on the last lag of R&D, with five lagged R&D terms in their model, was significantly higher than the coefficients of more recent R&D.[3]

Hausman et al. (1984) and Hall et al. (1986) analyzed the same research question whether there is a lag in the relationship between patenting and R&D expenditures. Using a more appropriate functional form that explicitly reflected the non-negativity and discreteness of patent counts in the context of panel data, Hausman et al. (1984) found a U-shaped lag structure in the random-effects estimation but not in their conditional fixed-effects version. When they conditioned their estimates on the total number of patents received by a firm over the observed years, no coefficients except for the contemporaneous R&D were statistically significant either

* Corresponding author at: Department of Organization and Strategy and UNU-MERIT, Maastricht University, The Netherlands. Tel.: +31 43 3883823; fax: +31 43 3884893.
E-mail addresses: N.Wang@maastrichtuniversity.nl (N. Wang), J.Hagedoorn@maastrichtuniversity.nl (J. Hagedoorn).
[1] Tel.: +31 43 3884793; fax +31 43 3884893.

[2] Internal R&D is usually measured as annual R&D expenditures by firms. A related question is to what extent patents serve as a good indicator of the output of R&D. Patents are directly related to inventiveness and represent an externally validated measure of technological novelty (Griliches, 1990). However, the use of patents as an economic indicator of knowledge increments has some limitations. For instance, not all inventions are patentable or patented, and the inventions that are patented differ greatly in their economic significance (Bound et al., 1984; Griliches, 1990; Pakes and Griliches, 1984a).

[3] The coefficient of the fifth year could be proxying for a series of small effects of the more basic research done six years ago or earlier, thus suggesting a lag "truncation" effect (Pakes and Griliches, 1984a). See Pakes and Griliches (1984b) for further discussion of this issue.

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in the Poisson or negative binomial model. Hall et al. (1986) found similar results and concluded that there was very little direct evidence of anything but simultaneity in the year-to-year movement of patents and R&D expenditures, though an indirect analysis performed in their study suggested a possible distributed lag structure.

The consistency of the previously described panel-data models[4] rests on the assumption that patents are an indicator of the output or 'success' of R&D rather than the input of R&D (Hall et al., 1986). However, as the patent application tends to occur relatively early in the life of a research project and the bulk of R&D expenditures often occur after the application is made, new patents virtually generate the need for future R&D expenditures (Griliches, 1990; Hall et al., 1986). Therefore, R&D expenditures should be seen as a predetermined variable instead of a strictly exogenous one. Such concern in the relationship of patents to internal R&D activity was first addressed by Hall et al. (1986) using a simple version of a Granger causality test, with a view to testing if past success in patenting leads to an increase in a firm's future R&D investments.[5] Montalvo (1997) applied a quasi-differenced generalized method of moments (GMM) estimator to the analysis of the patents–R&D relationship so as to obtain consistent estimates in the presence of predetermined regressors, i.e., R&D expenditures.[6] The results turned out to be somewhat inconclusive as well: the estimated coefficient on contemporaneous R&D was not statistically significant while the first lag of R&D had a significant effect on patents.

Blundell et al. (2002) extended the quasi-differenced GMM estimation with an application to a dynamic linear feedback model and proposed an alternative estimator, the pre-sample mean (PSM) estimator, based upon pre-sample information on the dependent variable. In their application to the analysis of the patents–R&D relationship, the results for the dynamic linear feedback model from the PSM estimator indicated a much lower depreciation rate of internal R&D investments – a potential long-run effect of in-house R&D on firm patenting – than that implied by the results from the multiplicative distributed lag model in prior literature. A recent study on the patents–R&D relationship by Gurmu and Pérez-Sebastián (2008) reported lagged R&D effects that were moderately higher than those previously found, but the lag effects on patents were identified only for more recent R&D.

So far the earlier work in this area, as aforementioned, has investigated the relationship between patenting and internal R&D activity of firms for the U.S. manufacturing sector during the 1970s (Blundell et al., 2002; Hall et al., 1986; Hausman et al., 1984; Montalvo, 1997; Pakes and Griliches, 1984a) and over the 1980s (Gurmu and Pérez-Sebastián, 2008). Our study aims to revisit this classic research question regarding the lag structure of the patents–R&D relationship by applying recently developed estimation techniques on firm-level panel data for the global pharmaceutical industry from 1986 to 2000. Prior research suggests that the relationship between patenting and internal R&D activity of firms differs across industries (Griliches, 1990; Hall et al., 1986). We attempt to address this concern by taking a closer look at the lag structure of the patents–R&D relationship within one industry. We focus on the global pharmaceutical industry for two main reasons. First, the pharmaceutical industry as a high-technology sector is characterized by high-levels of patenting propensity and R&D intensity. Previous studies demonstrate that patenting activity is an important source of technological advantage in the pharmaceutical industry (Henderson and Cockburn, 1994; Levin et al., 1987). In addition, recent figures show that pharmaceutical firms invest as much as five times more in R&D, relative to their sales, than the average U.S. manufacturing firm.[7] Second, empirical evidence clearly indicates that the proportion of research ('R') in R&D expenditures is the main contributor to patents, whereas the bulk of development ('D') costs lead more to products and processes (Czarnitzki et al., 2009).[8] Given that the 'D' part of R&D expenditures, relative to 'R', is mostly the larger one, the estimated patents–R&D elasticity would be biased downwards when development costs are of minor relevance for patent production (Czarnitzki et al., 2009; Griliches, 1990). As the pharmaceutical industry is actually among the most research-intensive sectors with a very large share of 'R', studying the pharmaceutical industry may alleviate the above-mentioned problem.

Our empirical analysis, using both a multiplicative distributed lag model and a dynamic linear feedback model, differs from previous work that examines the patents–R&D relationship in three aspects. First, our estimation results exhibit direct evidence on lagged R&D effects, with the first lag ($t-1$) of R&D being significant in all distributed lag specifications. Evidence for the contribution of the first lag of R&D to the current year's patent counts is of more than 25% of the total R&D elasticity. Second, a U-shaped lag structure of the patents–R&D relationship is found in most estimations of the multiplicative distributed lag model. This finding suggests a potential long-run effect of internal R&D investments on firm patenting. Finally, the estimation results from the dynamic linear feedback model coincide with those from the multiplicative distributed lag model, indicating not only lag effects from more recent R&D but also an overall long-run effect of internal R&D investments in the distant past on the knowledge production or innovation process of incumbent pharmaceutical firms.

The remainder of this paper is structured as follows: In Section 2, we provide the theoretical background to the expected lag effects of internal R&D investments by firms, lags effects that may last during the long run of the knowledge production or innovation process. In that section, we also formulate our main hypothesis. Section 3 describes the derivation of the data set and looks at the properties of the various variables. Section 4 proceeds by presenting the two count panel data models underlying our empirical analysis – the multiplicative distributed lag model and the dynamic linear feedback model – and their associated estimation techniques. The empirical results are reported in Section 5. Section 6 summarizes our main results and their implications and it then discusses some possible future lines of work.

[4] See Guo and Trivedi (2002) for a cross section analysis of the patents–R&D relationship. Their estimation results were in line with Hall et al. (1986).

[5] Following Hall et al. (1986), a Granger causality test was performed in this study as well (see the results shown in Appendix A: Table A1). The current level of Log R&D was predicted with two lags of Log R&D (based on an approximate AR (2) specification) as well as contemporaneous and lagged Log Patents. As shown from column (6) through (10), the estimated coefficient on contemporaneous Log Patents was significant, but lagged Log Patents were of no help in predicting future R&D. The same behavioral pattern of lagged Log Patents was identified even when contemporaneous Log Patents was left out of the equation in columns (11)–(14). Thus, there was no evidence suggesting that past success in patenting led to an increase in a firm's future R&D investments above and beyond that implied by its R&D history.

[6] Chamberlain (1992) and Wooldridge (1997) developed a quasi-differenced GMM estimator that is consistent for count panel data models with predetermined regressors. This quasi-differenced GMM estimator has been applied to the analysis of the patents–R&D relationship by Montalvo (1997), Crépon and Duguet (1997), Cincera (1997), and Gurmu and Pérez-Sebastián (2008).

[7] A CBO Study: Research and Development in the Pharmaceutical Industry, Publication No. 2589, Congressional Budget Office, October 2006, available at http://www.cbo.gov/ftpdocs/76xx/doc7615/10-02-DrugR-D.pdf.

[8] Using Flemish R&D Survey data, Czarnitzki et al. (2009) provided empirical evidence on the differential contribution of research ('R') and development ('D') to patents and identified a high premium of research ('R'), relative to overall R&D, toward firm patenting.