Irreversibility of R&D investment and the adverse effect of uncertainty: Evidence from the OECD countries

Rajeev K. Goel, Rati Ram*

Illinois State University, Department of Economics, Normal, IL 61790-4200, USA

Received 11 May 2000; accepted 7 November 2000

Abstract

Using annual data for nine OECD countries covering the period 1981–1992, we find a much sharper adverse effect of uncertainty on R&D investments, which are likely to be highly irreversible, than on non-R&D (and aggregate) investments. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: R&D outlays; Irreversibility of investment; Uncertainty

JEL classification: 05

1. Introduction

In recent studies of investment, two themes have been considered important. One is the effect of uncertainty, and the other relates to the consequences of investment irreversibility. Pindyck (1991); Pindyck and Solimano (1993) and Dixit and Pindyck (1994) integrated these two dimensions and proposed that irreversibility of investment accentuates the adverse effect of uncertainty. Several studies, including those by Pindyck and Solimano (1993); Favero et al. (1994); Episcopos (1995) and Bell and Campa (1997), have assessed empirically the effect of uncertainty on investment. The results seem somewhat mixed, and it is difficult to make a strong statement about the position. One reason for the mixed picture might be that most studies have treated investment in a largely undifferentiated manner relative to irreversibility, although it is reasonable to believe that the degree of irreversibility may vary considerably across different types of investment. More recently, Goel and Ram (1999)...

*Corresponding author. Tel.: +1-309-438-7101; fax: 1-309-438-5228.

E-mail address: rram@ilstu.edu (R. Ram).

Abel et al. (1996) note that investment may be characterized by both irreversibility and “expandability,” and that while irreversibility accentuates the adverse effect of uncertainty, expandability might mitigate it. R&D outlays probably have only a small amount of expandability but a high degree of irreversibility.
considered investment in different “sectors,” and noted some evidence of a stronger adverse effect of uncertainty in sectors where investment is more irreversible.

The effect of various types of uncertainties on R&D investments has also received considerable attention, notably in theoretical models of the kind discussed by Kamien and Schwartz (1980) and Reinganum (1989). However, as in several other studies of investment, this literature has not directly taken into consideration the potential role of irreversibility in the effect of uncertainty on R&D outlays. It is perhaps evident that R&D investments have a high degree of irreversibility. Almost all R&D expenditure on personnel, equipment and materials is irreversible since, to use Pindyck’s (1991, p. 1111) terminology, it is particularly firm-specific or industry-specific or has the “lemons problem”. In fact, a substantial part of R&D outlays might be extremely irreversible due to being project-specific, and not merely firm-specific or industry-specific. Dixit and Pindyck (1994, p. 424) emphasize the high irreversibility of R&D outlays by referring to models of “other irreversible decisions like spending on research and development”. The adverse effect of uncertainty on R&D outlays, therefore, is likely to be more severe than on many other types of investment. The main purpose of our study is to conduct an empirical investigation of the foregoing proposition by using annual data for nine OECD countries covering the period 1981–1992. The estimates indicate a rather dramatic contrast between the effect of uncertainty on R&D outlays and on non-R&D (and aggregate) investment.

2. The model, the data, and the main results

Broadly following Pindyck and Solimano (1993) and Goel and Ram (1999), we work with a simple model in which the share of investment in GDP is a linear function of uncertainty, real interest rate, and a measure of change in the level of aggregate economic activity. The model thus takes the following form

\[
(INV/GDP)_{it} = a + b_1(UNCERTAINTY)_{it} + b_2(RLR)_{it} + b_3(GRY)_{it-1} + u_{it}
\]

where the subscript \(i\) refers to the country and \(t\) to the period (year). As the discussion in Section 1 indicates, we compare the estimates, particularly the parameter for UNCERTAINTY, for R&D outlays, non-R&D investments, and the aggregate investment. Two measures of uncertainty are used. One is the 5-year moving standard deviation of inflation (STDINF), and the other is the 5-year moving average of inflation (MINF). The former (STDINF) reflects “inflation uncertainty,” which is likely to be associated with input and output prices. The latter (MINF) is included partly because inflation level and uncertainty are often positively related and partly because Pindyck and Solimano (1993) found average inflation to be one major correlate of economic “volatility”. It is evident that both measures of uncertainty capture aggregate uncertainty, and not firm-specific, product-specific or technology-specific uncertainties. That seems reasonable since our investment measures are also fairly aggregated. The proxy for the real interest rate is “real lending rate” (RLR), and change in economic activity (GRAY) is proxied by one-period lag on the rate of growth of real GDP, which, besides introducing some lag between change in economic activity and investment, makes the variable a little more predetermined.

Since data quality is important for a study of this kind, we focus on the OECD group, and use available information for the period after the oil shock of 1979. Due to missing information, we have
a total of 95 usable observations that pertain to nine OECD countries and cover the 12-year period from 1981 through 1992. Data on GDP and investment are taken from OECD (1983, 1994). R&D data are from National Science Board (1992) and OECD (1998). Non-R&D investment is computed by subtracting R&D outlays from (aggregate) gross domestic investment. Inflation rate is the annual percentage change in the CPI, and is based on International Monetary Fund (1995). Real lending rate is computed from annual average of nominal lending rate reported by International Monetary Fund (1986, 1995). The countries studied are Belgium, Canada, Denmark, France, Germany (FRG), Italy, Japan, U.K., and USA. Although these countries are fairly homogeneous in several ways, we use a fixed-effects format and include intercept dummies to capture country-specific effects of a simple kind.

Eq. (1) is estimated by the least-squares procedure (OLS), and the main results are summarized in Table 1. It compares the parameter structure for R&D investment with that for non-R&D outlays and aggregate investment.

Table 1
Comparing the effect of uncertainty on R&D (RDY), non-R&D (NRDY) and total investment (TINVY) in terms of Eq. (1) of the text

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Coefficient of Adj. R²</th>
<th>N</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>STDINF</td>
<td>MINF</td>
<td>RLR</td>
</tr>
<tr>
<td><strong>RDY</strong></td>
<td>-0.039*</td>
<td>0.015</td>
<td>0.012</td>
</tr>
<tr>
<td></td>
<td>(-2.24)</td>
<td>(1.74)</td>
<td>(1.29)</td>
</tr>
<tr>
<td><strong>NRDY</strong></td>
<td>0.031</td>
<td>-0.138</td>
<td>0.272*</td>
</tr>
<tr>
<td></td>
<td>(0.18)</td>
<td>(-1.68)</td>
<td>(3.20)</td>
</tr>
<tr>
<td><strong>TINVY</strong></td>
<td>-0.009</td>
<td>-0.123</td>
<td>0.283*</td>
</tr>
<tr>
<td></td>
<td>(-0.05)</td>
<td>(-1.54)</td>
<td>(3.44)</td>
</tr>
<tr>
<td><strong>RDY</strong></td>
<td>-0.038*</td>
<td>-0.006</td>
<td>-0.008</td>
</tr>
<tr>
<td></td>
<td>(-7.13)</td>
<td>(-0.82)</td>
<td>(-1.07)</td>
</tr>
<tr>
<td><strong>NRDY</strong></td>
<td>0.121*</td>
<td>-0.072</td>
<td>0.341*</td>
</tr>
<tr>
<td></td>
<td>(2.00)</td>
<td>(-0.82)</td>
<td>(3.80)</td>
</tr>
<tr>
<td><strong>TINVY</strong></td>
<td>0.083</td>
<td>-0.078</td>
<td>0.333*</td>
</tr>
<tr>
<td></td>
<td>(1.40)</td>
<td>(-0.91)</td>
<td>(3.77)</td>
</tr>
</tbody>
</table>

*Subject to data availability, the annual panel observations cover the period 1981±1992, and the countries included are Belgium, Canada, Denmark, France, Germany (FRG), Italy, Japan, U.K., and U.S.A. STDINF is 5-year moving standard deviation of inflation, MINF is 5-year moving average of inflation rate, RLR is real lending rate, and lagged(GRY) is one-period lag on rate of growth of real GDP. All equations include a constant term and eight country-specific “intercept dummies”. The estimates for these are not reported and are available on request. The numbers in parentheses are t-statistics, and an asterisk (*) indicates statistical significance at least at the 5% level.

2Use of OLS appears reasonable. The presence of fixed-effects dummies is likely to refine the main parameter estimates. Also, any “feedback” from sectoral (or even aggregate) investment to lagged growth rate or other regressors seems unlikely. At any rate, a simple version of RESET, explained by Ramsey and Schmidt (1976), was used to test for any major specification error. The simplest version of the test adds to Eq. (1) the square of the predicted value of the dependent variable from the model, and tests the significance of that added variable. The (absolute) value of the t-statistic for the added variable was less than 1.3 in all cases, indicating absence of any significant specification error.
Several preliminary points may be noted from Table 1. First, the fit of the simple model seems very good. Second, the general structure of estimates is fairly plausible. The parameters for the interest-rate variable are typically negative, although low in statistical significance, and most parameter estimates for the lagged-growth-term are positive and carry statistical significance at the conventional levels. Third, the pattern of estimates is similar for the two measures of uncertainty.

In regard to the parameters of primary interest, the most striking aspect is the dramatic contrast between the effect of uncertainty on R&D outlays and on non-R&D and aggregate investment. For each measure of uncertainty, the parameter for R&D outlays (\(RDY\)) is negative and carries high statistical significance. On the other hand, the uncertainty-parameters for non-R&D investment (\(NRDY\)) as well as for aggregate investment (\(TINVY\)) lack statistical significance at any meaningful level in most cases and even have the wrong sign. The evidence thus supports the Pindyck–Dixit proposition that investment irreversibility accentuates the adverse effect of uncertainty on investment. The estimates also suggest that the effect of uncertainty is likely to get blurred if one looks at investment in an undifferentiated manner without segregating it into categories with high and low degrees of irreversibility.

3. Concluding Observations

Using a simple model and reasonably good annual data for nine OECD countries covering the period 1981–1992, this study estimates equations for R&D, non-R&D and aggregate investment to compare the effect of uncertainty on these investments which are likely to differ in the degree of irreversibility. Subject to the caveats that are appropriate for such studies that use simple models and aggregate cross-country data, the estimates provide a striking illustration of the proposition that the degree of irreversibility of an investment has an important relation with the effect of uncertainty, and that a higher degree of irreversibility accentuates the adverse effect of uncertainty.\(^3\) For R&D outlays, which are likely to be highly irreversible, the effect of two general measures of uncertainty is negative and has strong statistical significance. For non-R&D outlays, which are likely to be less irreversible, the effect of uncertainty has the wrong sign. For aggregate investment, the uncertainty parameters lack statistical significance at the conventional levels. The estimates also illustrate the point that if investment is treated in an undifferentiated manner without being segregated by degree of irreversibility, the adverse effect of uncertainty is likely to get blurred. Last, our study makes some contribution to the literature on economics of technological change. Theoretical models of the effect of uncertainty on R&D spending appear to be far ahead of the related empirical investigations. While the level of aggregation in our data does not enable us to capture firm- or technology-specific uncertainties, the estimates indicate that aggregate uncertainty, and possibly other types of uncertainties, have a strong adverse effect on R&D spending, and that irreversibility of R&D outlays might be a major factor behind such an effect.

\(^3\) Besides other well-known aspects, Griliches (1979) explains several measurement problems in the data on R&D expenditures.
Acknowledgements

We are grateful to the staff at the Institute of Statistics, UNESCO, Paris, especially S. K. Chu and Bertrand Tchatchoua, for help in finding data on R&D expenditures. An earlier version of this paper was presented at the Bank of Finland, Helsinki in July 2000.

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