Investments in R&D and business performance. 
Evidence from the Greek market.

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ABSTRACT

The purpose of the present paper is to discuss the question: are investments in R&D, innovation and new technologies, intangible factors of business performance? There is a great controversy concerning the relationship between profitability and investments in research and development. Many studies have failed to identify consistent positive returns from R&D and IT investments, and the paradox has been termed as the “IT productivity paradox”. Most of the optimistic researchers argue that the disappointing results are due to mismeasurement errors, problematic design of the research and time lags between learning and adjustment, because R&D investments can take several years to show results. In our research, we apply a panel data analysis using data from industrial and computer companies listed in the Athens Stock Exchange, for the period 1995-2000. We find that although the R&D investments have a negative influence on profitability for the year of the investment, they can show strong positive relation after two years.

Keywords: Performance, R&D, profitability, firm level data, Greek market, productivity paradox, R&D strategy.

JEL Classification: O300, L250, M200, L190

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1. Introduction

In a competitive environment, firms are forced to adopt strategies in order to confront competition, increase profitability and market share. R&D investment has an essential role in these strategies, although it has distinguished characteristics from other investments. Since more than half of the investments are associated with salaries of skilled – expert workers and scientists, the degree of uncertainty associated with its output may influence the investment rate over time (Hall, 2000). R&D investment generates profits with a time lag (Aboody and Lev, 2001; Jefferson, 2006), and hence should be sustained at a certain level (Hall 2002).

The continuous substitution of knowledge (intangible capital) for physical (tangible capital) the last decades, has shown the important role of R&D on the performance of the firms (Lev, 1999). R&D investment has been studied from several different perspectives. Thorough research using a production function approach has been done by Griliches as early as 1979. Verspagen and Los (2000) researched the R&D spillovers and productivity, while Hall (2002) studied the financing of R&D. Aboody and Lev (2001), Ding, Stolowy and Tenenhaus (2007), Jefferson, huamao, Xiaojing and Xiaoyun (2006), studied the time lag of R&D on profitability and the contribution to the future earnings of the firm. In addition to those studies, Lev and Sougiannis (1996) found a positive correlation between R&D expenditures and economic growth.

The questions addressed in this paper aim to research the influence of R&D on profitability, the time period for profit realization and the existence of decreasing returns.
We used data from the balance sheets of 36 industrial and computer firms listed in the Athens Stock that report R&D stock, from the total 143, for the period 1995-2000. Using panel data estimations, we found that R&D needs at least two years to positively affect profitability. Moreover, this impact exhibits decreasing returns.

The paper is organized as follows: Section 2 gives the theoretical framework. Section 3 describes the data, presents the methodology and discusses the empirical results. Finally, section 4 offers some concluding remarks and policy implications.

2. Theoretical framework

R&D and implementation of new technologies, for products development and innovative production processes, are used in order to provide differentiation that can yield competitive advantage and lead time over rivals (Mansfield, 1968; Baily, 1972). Hence, the firm invests in R&D and innovation to achieve market share and monopolistic profit.

Hall (2000) states, that more than 50% of the R&D spending is associated with salaries and wages of highly educated scientists and engineers. Their efforts create an intangible asset (know how), from which profits in future years will be generated. Low investment in R&D reduces innovation and knowledge creation, which in turn reduces productivity as well as investments in both physical and human capital (Rogers, 2005).

R&D has generally been ignored, partly due to data availability problems. Sougiannis (1994) notes that most of the results that show no significant relationship between R&D and future benefits, may be due to sample sizes, research design, statistical techniques and
quality of the R&D data used. Studies in research intensive industries show that R&D investments give above average returns (Grabowski, 1978).

A business unit with higher productivity is generally more profitable. There are many other factors that influence performance, that we should take into consideration in order to check the importance of innovative intangible capital stock.

Hence, we posit the following hypothesis.

**Hypothesis 1.** R&D stock is related to profitability.

The time lags are a major concern in the data and analysis. First of all a research may take a few years to complete. After completion, it may take a couple of years to start showing results (Griliches, 1979). This may be one of the most important reasons to check variation over time and to research more than 5 years of firm level data. Some of the studies use 15 years of data.

Jefferson (2006) finds that the returns to industrial R&D appear to be at least three to four times the returns to fixed production assets. There is a direct positive correlation between R&D expenditures and economic growth. Lev & Sougiannis (1996) found that the useful life of R&D varies from 5 to 9 years, while Aboody & Lev (2001) conclude that the estimated duration of the benefits from R&D projects is seven years and most of the operating income benefits are generated in 3 years from the R&D investment. Hence, we posit the following hypothesis.

**Hypothesis 2.** There is a time lag for the R&D stock to show results.
If we assume the production function exhibits the usual properties, then the R&D stock as a production factor should exhibit decreasing marginal returns. Thus, we posit the 3rd hypothesis.

*Hypothesis 3. The R&D stock exhibits decreasing returns.*

3. Data, Methodology and Empirical Results

We used data from the balance sheets of 36 industrial and computer firms listed in the Athens Stock that report R&D stock, from the total 143, for the period 1995-2000. The firms are the most important manufacturing and computer firms in Greece.

We define gross profit to sales ratio (GPSL) as a proxy for business performance. We used the gross profit to sales ratio as the depended variable in our model, because it is more closely related to monopolistic profit.

Firms that report R&D investments in their balance sheets, include research and development expenditures for new products development, innovations in production, software systems, brand development and other intangibles. Hall and Hayashi (1989), state that R&D is an important intangible capital that can lead to more long-lasting and supranormal returns; it is embodied in the firm and its employees and includes knowledge, accumulated know-how, technical expertise, trade secrets, patents, etc. Knowing that, we used the R&D stock to total assets, denoted as *RDTA*, as an explanatory variable in our model.

We finally used the following control variables: first, the cost of goods sold to inventories ratio denoted as *CGSINV*, as a proxy for the corporate management and second
the size of the firm proxied either by the logarithms of sales ($SIZE$) or by the logarithm of fixed assets ($LFA$).

Tables 1 and 2 present the descriptive statistics and the correlation matrix of the variables used in our models. Data show a 28.4% average gross profit to sales ratio and an average of 1.8% R&D stock to total assets. In accordance to our findings, Voulgaris, Asteriou and Agiomirgianakis (2004), also calculated an average of 25% for gross profit ratio for SMEs and an average of 28% for LSEs, in their sample from the manufacturing sector.

Following the discussion of the previous section, the relationship between firms’ performance and the explanatory variables is modeled as follows:

$$Profitability = f(research \ and \ development, \ control \ variables)$$

Where $GPSL$ stands for profitability, $RDTA$ with one and two lags stands for research and development and $SIZE$, $LFA$ and $CGSINV$ as control variables. Finally, to test the 3rd hypothesis for decreasing returns to R&D we included the squared $RDTA$ with two lags.

Table 3 presents the panel estimations. In estimating panel data the unobserved effect or individual heterogeneity is random and should be tested for random effect or fixed effect. If the unobserved effect is uncorrelated to the observed explanatory variables ($cov(x_{it},c_{i})=0$, $t=1,2,...T$) is called random effect otherwise fixed effect. Hausman test suggested, in our case, that the unobserved effect is correlated to the observed explanatory variables and therefore the fixed effect method is more robust than random effects analysis for the estimation of the parameters. The cost of this robustness is the exclusion of the
time-constant observables. However, since our data set does not include any time constant observable explanatory variable, this cost is relatively low.

We conclude that R&D investments have a negative influence on performance, for the year following the year of the investment, since the novelty of the methods introduced to production processes requires a learning and adjustment period. The strong positive coefficient on the $[RDTA]_{t-2}$ term explains that there is a positive influence of R&D on the profitability of the firm on the following 2 years. This means that, we have to wait for 2 years after the investment in order to have strong positive returns in $GPSL$. Hence, our first and second hypotheses are valid and R&D is related to profitability and there is a time lag in order for the R&D investments to show results.

Based on our findings, we suggest smooth and consistent investments in R&D. The managers have to wait for 2 years in order to have positive results from R&D. From our experience from the internet industry, internet companies need a period of two years from new product development and R&D investments, in order to increase sales and profits. Hence, companies with late reaction to the competition need around 2 years to react to the new technologies, and another 2 years after implementation, concluding to a time span of four years. Branch (1974) finds that there is a lag of 4 years between introducing an innovation to practice and receiving a patent on it. That is why he used the patents received in year $t$ as an index of a firm’s R&D output in year $t-4$.

The negative coefficient on the $[RDTA]_{t-2}^2$ term suggests that the third hypothesis for the existence of decreasing marginal returns is supported by the data. Therefore, the continuous increase of R&D share to total assets is not followed by equivalent increase in
profitability and even more the level of R&D investment has an upper limit after which profitability decreases. In order to estimate the upper level of $RDTA$, we take the partial derivative of $GPSL$ with respect to $[RDTA]_{t-2}$ from the (A2) model in Table 3. Hence:

$$\frac{\partial GPSL}{\partial [RDTA]_{t-2}} = 0 \Rightarrow b_1 + 2b_2[RDTA]_{t-2} = 0 \Rightarrow [RDTA]_{t-2} = 0.157$$

Where $b_1$ is the estimated coefficient of the $[RDTA]_{t-2}$ and $b_2$ is the estimated coefficient of the squared $[RDTA]_{t-2}$. Thus, the upper limit for R&D as share of total assets is 15.7% and after that profitability decreases. Using the partial derivative of $GPSL$ with respect to $[RDTA]_{t-2}$ from the (A2) model, we also find that an increase on the share of R&D to total assets by of 1% leads to an increase on $GPSL$ by 1.69%, in the following two years.

$$\frac{\partial GPSL}{\partial [RDTA]_{t-2}} = b_1 + 2b_2[RDTA]_{t-2} = 1.975 - 2 \cdot 6.269 \cdot 0.023 = 1.69$$

$CGSINV$ show a negative influence on performance in all our models. This means that lowering the stock the performance decreases, in contrast older findings that, it is large inventories that create a drag on firm’s performance (Chhibber and Majumdar, 1999). This may be due to the fact that further lowering inventories leads to operational and sales problems.

Finally, the size has a negative influence on gross profit margin (in contrast to the theory). This may be true for Greece as the major companies are old, former state owned companies, and we find in literature that the age of the firm has a negative influence on performance (Majumdar, 1997). Moreover, although a positive relationship between size
and profitability is expected, firms that grow at a rate faster than that which the entrepreneur can manage may experience diseconomies of scale which reduce profitability (Glancey, 1998).

4. Conclusions and policy implications

In our study we undertook an empirical investigation using panel data methodology for 36 industrial and computer companies listed in the Athens Stock that report R&D stock, for the period 1995-2000. Our findings suggest that the effect of R&D investment on profitability becomes positive after a period of two years with decreasing returns.

More specifically, the production costs tend to increase in the short run, because new product development, new production methods and information technology, need time to show results, since the novelty of the methods introduced into the production processes creates turmoil during the adjustment period. That explains the negative relation of R&D to profitability for the subsequent of the investment year. Finally, 2 years after the R&D investment, the new methods and improvements are fully functional and absorbed and we can see positive returns on profitability, but with decreasing results.

Although we have results in accordance to the theory, further research should be done using data from the income statements of the firms, as many of the R&D expenditures are calculated in the income statements and not to the balance sheet. Only the 30% of the companies in the Athens Stock Exchange calculate R&D expenditures in their balance sheet. Matteucci and Sterlacchini (2005), also found that only 34% of their sample from Italian manufacturing firms, do report R&D expenditures. We can also find in the literature that most companies do not capitalize R&D, even when accounting standards allow them
the option. The difficulty on modeling such a research is that many of the R&D expenditures are calculated in the income statements as production costs and not specifically as an R&D figure. Furthermore, R&D and innovation is a value that many times is not calculated in the financial statements. Lev (2003), comments that most companies do not report how much they spend on employee training, on brand enhancement, or on software technology. Most of the times, R&D and innovation is an intangible asset that has to do with entrepreneurship and the owner’s innovative ideas. Many of the assets bought for production, involve high technology and R&D, but the extra value is paid as a product and is not calculated in the balance sheet. The companies should calculate this extra value and take it into account in the intangibles, with annual depreciation, and not just calculate it as expenses in the income statement. Though, this direction deals with the personality and education of the entrepreneur. Lev (2003) comments that managers tend to manipulate and immediately expense R&D expenditures in order to meet profit goals. The same problem arises when many innovative products and R&D expenses are paid through operating leasing and hence they are also calculated as production expenses in the income statement.
References


### Appendix

#### Table 1: Descriptive Statistics

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std Dev</th>
<th>Minimum</th>
<th>Maximum</th>
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</thead>
<tbody>
<tr>
<td>GPSL</td>
<td>0.284</td>
<td>0.117</td>
<td>0.058</td>
<td>0.597</td>
</tr>
<tr>
<td>RDTA</td>
<td>0.018</td>
<td>0.030</td>
<td>0.000</td>
<td>0.187</td>
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<tr>
<td>({RDTA}_{t-1})</td>
<td>0.022</td>
<td>0.036</td>
<td>0.000</td>
<td>0.201</td>
</tr>
<tr>
<td>({RDTA}_{t-2})</td>
<td>0.023</td>
<td>0.037</td>
<td>0.000</td>
<td>0.201</td>
</tr>
<tr>
<td>SIZE</td>
<td>17.612</td>
<td>1.182</td>
<td>15.669</td>
<td>21.909</td>
</tr>
<tr>
<td>LFA</td>
<td>17.052</td>
<td>1.396</td>
<td>13.143</td>
<td>20.732</td>
</tr>
<tr>
<td>CGSINV</td>
<td>7.051</td>
<td>11.674</td>
<td>0.869</td>
<td>70.446</td>
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#### Table 2: Correlation Matrix

<table>
<thead>
<tr>
<th></th>
<th>GPSL</th>
<th>({RDTA}_{t-1})</th>
<th>({RDTA}_{t-2})</th>
<th>({RDTA}_{t-2}^2)</th>
<th>SIZE</th>
<th>LFA</th>
<th>CGSINV</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPSL</td>
<td>1</td>
<td>-0.629</td>
<td>-0.752</td>
<td>-0.120</td>
<td>-0.273</td>
<td>-0.150</td>
<td>-0.165</td>
</tr>
<tr>
<td>({RDTA}_{t-1})</td>
<td>-0.629</td>
<td>1</td>
<td>-0.934</td>
<td>-0.853</td>
<td>-0.050</td>
<td>-0.260</td>
<td>0.121</td>
</tr>
<tr>
<td>({RDTA}_{t-2})</td>
<td>-0.752</td>
<td>-0.934</td>
<td>1</td>
<td>-0.921</td>
<td>-0.073</td>
<td>-0.327</td>
<td>0.033</td>
</tr>
<tr>
<td>({RDTA}_{t-2}^2)</td>
<td>-0.120</td>
<td>-0.853</td>
<td>-0.921</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SIZE</td>
<td>-0.273</td>
<td>-0.050</td>
<td>-0.073</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LFA</td>
<td>-0.150</td>
<td>-0.260</td>
<td>-0.327</td>
<td>0.783</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CGSINV</td>
<td>-0.165</td>
<td>0.033</td>
<td>0.095</td>
<td>-0.020</td>
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</tr>
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### Table 3: Panel estimations: Dependent variable GPSL

<table>
<thead>
<tr>
<th></th>
<th>Model A1</th>
<th>Model A2</th>
<th>Model B1</th>
<th>Model B2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$[RDTA]_{t-1}$</td>
<td>-0.823**</td>
<td>-0.698**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-2.558)</td>
<td>(-2.317)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$[RDTA]_{t-2}$</td>
<td>1.041***</td>
<td>1.975***</td>
<td>0.950**</td>
<td>1.961***</td>
</tr>
<tr>
<td></td>
<td>(2.826)</td>
<td>(2.906)</td>
<td>(2.566)</td>
<td>(2.886)</td>
</tr>
<tr>
<td>$[RDTA]_{t-2}^2$</td>
<td>-6.269*</td>
<td></td>
<td>-6.412**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-1.948)</td>
<td></td>
<td>(-0.996)</td>
<td></td>
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<tr>
<td>CGSINV</td>
<td>-0.102*</td>
<td>-0.106*</td>
<td>-0.129**</td>
<td>-0.125**</td>
</tr>
<tr>
<td></td>
<td>(-1.688)</td>
<td>(-1.720)</td>
<td>(-2.097)</td>
<td>(-2.022)</td>
</tr>
<tr>
<td>SIZE</td>
<td>-0.035***</td>
<td>-0.018*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-2.649)</td>
<td>(-1.665)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LFA</td>
<td></td>
<td>-0.015**</td>
<td>-0.960*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-2.603)</td>
<td>(-1.720)</td>
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<tr>
<td>$R^2$ adjusted</td>
<td>0.929</td>
<td>0.926</td>
<td>0.929</td>
<td>0.926</td>
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<tr>
<td>F-statistic</td>
<td>36.142</td>
<td>33.498</td>
<td>37.514</td>
<td>34.588</td>
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<tr>
<td>Prob(F-statistic)</td>
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<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
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<tr>
<td>Hausman test</td>
<td>$x^2(4) = 1.224$</td>
<td>$x^2(4) = 5.507$</td>
<td>$x^2(4) = 2.478$</td>
<td>$x^2(4) = 7.609$</td>
</tr>
<tr>
<td></td>
<td>p=0.874</td>
<td>p=0.239</td>
<td>p=0.648</td>
<td>p=0.107</td>
</tr>
</tbody>
</table>

* T statistic in parentheses.
***, **, * indicate a significance at the 1%, 5% and 10% levels respectively.