THE RELATIONSHIP BETWEEN R&D EXPENSES AND PERFORMANCE: EVIDENCE FROM EUROPEAN MANUFACTURING ENTERPRISES

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ABSTRACT
Measuring performance and contribution of R&D to performance has become a critical concern for managers and executives. This paper illustrates a link between R&D expenses and performance through a statistical model. We test whether and how innovation influences performance. Therefore, we consider R&D expenses (the independent variable) and other financial indicators of the enterprise's performance (the dependent variables). Enterprises from manufacturing industries have been chosen as an examined sample. The data was obtained from the Amadeus database in the period 2007 to 2012. From a managerial point of view, such a model should be useful in predicting how enterprises may invest in new R&D capabilities in the future. We found significant relationship between the return on assets and past R&D expenses. The main limitation of our analysis is, that data provide only a view into medium and large-sized companies due to focus on top R&D investing companies in the EU.

Keywords: R&D expenses, performance measurement and management, statistical model in measurement, European manufacturing companies.

1. INTRODUCTION

Innovation is generally considered as a major cause of enterprise's performance growth. In addition, the examination of the impact of innovation on enterprise's survival has shown that the ability to innovate increases survival probabilities for all enterprises across most manufacturing sectors (Cefis and Ciccarelli, 2005).

However, it is not clear that innovation has actually a positive impact on an enterprise's profits. Innovation may be considered as a largely random and unpredictable phenomenon (Brusoni et al., 2006). The relationship between innovation and performance (measured by R&D expenses and return on assets) is a priori unclear and it is by no means clear that innovative activities really lead to higher returns at the microeconomic level. Furthermore, a large part of all R&D expenses may no return at all and whether the innovative activities have a positive return on average is a matter that is not clear at the outset.

Many researches are conducting studies to determine the degree to which R&D really improves an enterprise's performance (Bae and Kim, 2003; Chauvin and Hirschey, 1993; Smith, 2006; Szewczyk et al., 1996; Youndt et al., 2004). Czarnitzki and Kraft [2010] proved that innovation has a strong a robust impact on profitability. An innovating enterprise realizes an about 0.67 percentage points higher return on sales than an enterprise not performing innovations, on average. Therefore, enterprises invest into R&D in order to maximize their individual profits (Czarnitzki and Kraft, 2010).

There seems to be general agreement that the accounting definition of R&D is incredibly loose. It is also the case that output from various R&D processes may differ fundamentally. Research ranges, where the goal is to advance the state of the art along a predetermined dimension (Marshall, 1980).

More likely is that the R&D process is affected on the input side. Labor, capital, materials, and energy are combined to produce knowledge. Prominent Czech expert in innovation Valenta (1969, 2001) defined chain activity-innovation-effect. The activity presents human creativity, which lead into invention. Invention is knowledge basis for innovation. Well-managed and successfully-introduced innovation into the market gives rise to final effect.

In spite of the abundance of books and publication written over past few years in the field of performance measurement, the problem of defining a rigorous model for measuring innovation and its impact on company financial performance has not been solved yet (Lazzarotti et al., 2011; Neely, 2005), although some notable and interesting attempts have been recently published (Apergis et al., 2013; Carayannis and Provance, 2008; Smith, 2006; Tohumcu and Karasakal, 2010). The most typical indicator used is R&D expenses (Gault, 2013; OECD, 2002; OECD, 2005).

In general, we can understand R&D expenses as an expenses associated with the R&D of an enterprise's goods or services. R&D expenses are a type of operating expense that can be deducted as such on the business tax return. This type of expense is incurred in the process of finding and creating new products or services.

R&D expenses can be relatively minor, or they can easily run into the billions of dollars for large enterprises. R&D expenses are usually the highest for industrial, technological, healthcare and pharmaceutical enterprises. Some companies reinvest a significant portion of their profits back into R&D, as they see this as an investment in their continued growth.

World industrial R&D spending has reached a level of € 373 billion and is expected to grow continuously, in spite of the financial crisis and restructuring of the world economy after 2008 (Gerybadze, 2010).

We consider R&D expenses as an accounting item for which measurement under International Financial Reporting Standards (IFRS) are likely to differ considerably from measurements under domestic accounting systems across the EU countries prior to the mandatory introduction of the IFRS.

The scientific aim of this paper is to analyze the relationship between the current performance of an enterprise measured by the return on assets indicator and past R&D expenses. We focus on manufacturing enterprises, since this is the sector that undertakes the majority of total business R&D. In this paper, R&D expenses is expressed relatively, as a ratio of R&D expenses and other items in the same period (for example, number of employees, added value, value of fixed assets, etc.).

The paper is organized as follows. After introduction to basics and essential definition in view of interpreting them in the case of R&D managers and executives, the next section describes research method and basis for models. Section 3 presents the results and models of relationship between R&D expenses and performance of enterprise. Section 4 synthesis the highlights of our work, outlines some of its limitation, any suggests some direction for future research.

2. RESEARCH METHODS

The purpose of our paper, as previously stated, is to contribute to the knowledge of innovation by creating a link between innovation and performance from a managerial point of view. Considering the European manufacturing enterprises, we stated the following research question:

Is there a relationship between performance (measured by return on assets) and R&D expenses?

From the theoretical point of view, the goal of creating such a link is consistent with the data. The sample under our evaluation comprises 2,666 private enterprises active in the processing industry (NACE rev. 2 Main section C: Manufacturing) from the EU 28 countries in the period 2007 to 2012. The data was obtained from the Amadeus database provided to the company Bureau Van Dijk.

The performance of an enterprise is measured by the return on assets indicator or, in other words, the EBIT and total assets (ROA) ratio. The reason we use ROA a measure of performance is represented by characteristic of this ration. It allows the enterprise financing strategy to be neutral with respect to the performance (Ferrari and Rocca, 2010) and comparison among companies in the sample to be favored.

As regards R&D expenses, we take into consideration the total amount of expenses on research and development activities reported in Amadeus database according to IFRS. The relative R&D expenses has been defined in the following ways:

1. R&D expenses and sales ratio (RD/S) – expresses the proportion of R&D expenses per unit of sales in the given year, in other words the relative amount of R&D expenses where sales represent the size of the enterprise.
2. R&D expenses and number of employees ratio (RD/Empl.) – expresses the proportion of R&D expenses per employee in the given year,
3. R&D expenses and fixed assets ratio (RD/FA) – expresses the proportion of R&D expenses per unit of fixed assets in the given year.
4. Employee cost and R&D expenses ratio (EC/RD) – expresses the proportion of employee cost per unit of R&D expenses in the given year,
5. EBIT and R&D expenses ratio (EBIT/RD) – represents the profits (EBIT) per unit of R&D expenses,
6. Added value per R&D expenses ratio (AV/RD) – represents the degree of covering R&D expenses from added value.

Values beyond the interval (μ-3σ; μ+3σ) were removed from the sample of data under examination.

The analysis of the relationship between performance and R&D expenses was carried out in two stages; in the first stage the correlation was examined between the ROA values for 2012 and the values of relative R&D expenses in the years 2012-2007. To this end, Spearman's correlation coefficient was applied, particularly due to its non-parametric assumptions:

$$\rho = \frac{6\sum_{i=1}^{n}(p_i - q_i)^2}{n(n^2 - 1)} \quad (1)$$

where

p_i or q_i refers to the ranking of x_i or y_i values for the random quantity X or Y,

n refers to the number of observations/number of values x_i or y_i

In the second stage, a regression model was set up with only those variables (relatively defined R&D expenses) that showed a statistically significant correlation to the 2012 ROA, at least at a 5% significance level. The purpose of the model is to determine as to what degree the current performance (ROA) is influenced by past R&D expenses.

We assume that there is a quadratic dependence between the performance of enterprises and R&D expenses. The reason is that on the one hand, growing R&D expenses suggests an innovative activity which, if successful, leads to lower cost or higher revenues. On the other hand, these costs decrease profits or EBIT no matter whether the innovation is successful. In other words, we assume that there is a theoretical value of relative R&D expenses which maximizes the current ROA.

To describe this dependence, we shall apply the following generalized model of linear regression (generalized linear model – GLM):

$$ROA_t = \alpha_{t-i} + \cdot \beta X_{t-i} + \gamma \cdot X_{t-i}^2 + \varepsilon = \alpha_{t-i} + \beta_1 x_{1(t-i)} + \beta_2 x_{2(t-i)} + \gamma_1 x_{1(t-i)}^2 + \gamma_2 x_{2(t-i)}^2 + \ldots + \beta_n x_{n(t-i)} + \gamma_n x_{n(t-i)}^2 + \varepsilon \quad (2)$$

where

ROA_t refers to the return on assets in year t where t stands for the year 2012,

i refers to the number of periods prior to year *t* where $i = 0,1,\ldots,5$

α, β refer to regression coefficients,

X_{t-i} represents a vector of independent variables defined in time, *t-i*

3. EMPIRICAL FINDINGS

The following table shows the values of correlation between ROA in 2012 and the given relatively defined R&D expenses in the period *t-i*.

Table 1: Values of Spearman's correlation coefficient between ROA in 2012 and the given relative R&D expenses in the given period

	No.	Spearman	t (N-2)	p-value		No.	Spearman	t(N-2)	p-value
RD/S_12*	143	0,1447	1,7370	0,084572	EC/RD_12	297	-0,0761	-1,3109	0,190923
RD/S_11	147	0,1282	1,5571	0,12162	EC/RD_11	292	-0,0368	-0,6265	0,531455
RD/S_10	146	0,1193	1,4418	0,151528	EC/RD_10	288	-0,0331	-0,5607	0,57542
RD/S_09	147	0,1097	1,3296	0,185747	EC/RD_09	153	-0,0533	-0,6556	0,513102
RD/S_08	146	0,1127	1,3612	0,175572	EC/RD_08	27	0,1319	0,6652	0,512045
RD/S_07	154	0,1028	1,2747	0,204358	EC/RD_07	24	0,1670	0,7942	0,435538
RD/Empl_12**	419	0,1493	3,0841	0,002177	EBIT/RD_12***	368	0,6011	14,3894	0,000000
RD/Empl_11**	412	0,1072	2,1838	0,029542	EBIT/RD_11***	365	0,3757	7,7243	0,000000
RD/Empl_10	411	0,0725	1,4697	0,142417	EBIT/RD_10***	356	0,3142	6,2274	0,000000
RD/Empl_09	276	0,0834	1,3857	0,166977	EBIT/RD_09***	221	0,2786	4,2921	0,000027
RD/Empl_08*	146	0,1379	1,6705	0,096999	EBIT/RD_08***	99	0,3784	4,0259	0,000113
RD/Empl_07	154	0,1213	1,5065	0,134021	EBIT/RD_07*	106	0,1724	1,7853	0,077127
RD/FA_12***	422	0,1940	4,0528	0,000060	AV/RD_12	259	0,0312	0,5002	0,617335
RD/FA_11***	419	0,1761	3,6539	0,000291	AV/RD_11	254	0,0059	0,0931	0,925908
RD/FA_10***	404	0,1577	3,2017	0,001475	AV/RD_10	252	0,0069	0,1095	0,912896
RD/FA_09***	274	0,1730	2,8969	0,004076	AV/RD_09	135	-0,0609	-0,7037	0,482878
RD/FA_08**	147	0,1647	2,0111	0,046166	AV/RD_08	22	0,0322	0,1440	0,886933
RD/FA_07**	155	0,1652	2,0714	0,040003	AV/RD_07*	15	0,4857	2,0035	0,066426

Note: *significant at a 10% level, **significant at a 5% level, ***significant at a 1% level
Source: Own processing of data from the Amadeus database.

It is obvious from the table 1 that the R&D expenses and sales ratio (RD/S) does not have a statistically significant effect in any manner, at the 5% significance level, the enterprise performance values evaluated using ROA in any of the past periods under survey.

However, a statistically significant relationship exists in the same year, 2012, although only at the 10% significance level. This can be explained by the fact that R&D expenses reduces EBIT.

The employee cost/R&D expenses ratio or added value/R&D expenses ratio does not have a significant effect on the ROA values in 2012 at any standard significance level in any of the periods under survey.

In contrast, the R&D expenses per employee (RD/Empl.) values in the same year, as well as in the previous year, have an effect on ROA in 2012 at a statistically significant level, namely 5%. However, the correlation values reported are relatively low.

Stronger correlations can be identified between the 2012 ROA and the R&D expenses/fixed assets ratio defined for the years 2007 to 2012. In other words, such relatively defined R&D expenses has an effect on performance measured by the ROA relationship up to 5 years in advance.

The strongest correlation of all was identified between ROA in 2012 and the EBIT/R&D expenses ratio defined for the years 2008 to 2012. In other words, such a relatively defined R&D expenses has an effect on performance measured by the ROA relationship up to 4 years in advance.

Indicators that show a statistically significant correlation to ROA, at least at a 5% significance level, were used to set up a model or as an independent model variable in the (2) form. These indicators were RD/FA and EBIT/RD defined for the years 2008 to 2012. The role of dependent variable is given to the ROA indicator defined for 2012. The following table shows the descriptive statistics of these variables.

Table 2: Descriptive statistics of ROA indicators (2012), RD/FA (2012-2018), EBIT/RD (2012-2008)

Variable	N.	Mean	Min.	Max	quant. (25%)	quant. (50%)	quant. (75%)	quant. (90%)	quant. (95%)	std. dev
ROA_2012	2579	0,078	-0,541	0,711	0,023	0,068136	0,126	0,207	0,262	0,11239
RD/FA_2012	424	0,196	0,000	2,296	0,008	0,042552	0,197	0,663	0,960	0,35886
RD/FA_2011	421	0,202	0,000	2,389	0,008	0,043668	0,184	0,606	0,957	0,38208
RD/FA_2010	406	0,154	0,000	1,578	0,011	0,04704	0,169	0,475	0,711	0,25914
RD/FA_2009	275	0,154	0,000	1,719	0,004	0,043054	0,165	0,466	0,716	0,27004
RD/FA_2008	148	0,165	0,000	1,362	0,000	0,042526	0,221	0,491	0,755	0,26106
EBIT/RD_2012	370	10,419	-143,333	158,276	0,544	3,561111	11,459	33,890	65,729	28,2159
EBIT/RD_2011	367	12,494	-157,118	202,778	0,863	3,286011	13,018	42,750	61,333	33,5472
EBIT/RD_2010	359	9,107	-55,430	113,394	0,700	3,585818	10,793	26,438	47,037	18,2143
EBIT/RD_2009	222	5,847	-90,114	127,641	-0,462	1,761475	7,121	16,457	29,725	20,8587
EBIT/RD_2008	100	4,838	-20,524	46,810	0,417	2,373614	6,410	13,933	23,291	9,2822

Source: Own processing of data from the Amadeus database

The model for these applied variables can be transformed into the following formula:

$$ROA_t = \alpha_{t-i} + \beta_1 (RD/FA)_{t-i} + \beta_2 (EBIT/RD)_{t-i} + + \gamma_1 (RD/FA)^2_{t-i} + \gamma_2 (EBIT/RD)^2_{t-i} + \varepsilon \quad (3)$$

Assuming that the parameters γ_1, β_1, γ_2, β_2 are statistically significant in the given model, it is reasonable to look for the values of indicators RD/FA_{t-i} or $EBIT/RD_{t-i}$ that maximize the ROA_t values. These values can be found when placing the first partial derivative of the ROA_t function under RD/FA or EBIT/RD at equal to zero, as follows:

$$\frac{dROA_t}{d(RD/FA)_{t-i}} = \beta_1 + 2\gamma_1 (RD/FA)_{t-i} = 0 \quad (4)$$

Then the RD/TA_{t-i} value maximizing ROA_t

$$\beta_1 + 2\gamma_1 (RD/FA)_{t-i} = 0 \rightarrow (RD/FA)_{t-i} = = -\frac{\beta_1}{2\gamma_1} \quad (5)$$

This value will maximize ROA_t if $\gamma_1 < 0$.

Or

$$\frac{dROA_t}{d(EBIT/RD)_{t-i}} = \beta_2 + 2\gamma_2 (EBIT/RD)_{t-i} = 0 \quad (6)$$

Then the $EBIT/RD_{t-i}$ value maximizing ROA_t

$$\beta_1 + 2\gamma_1 (EBIT/RD)_{t-i} = 0 \rightarrow (EBIT/RD)_{t-i} = = -\frac{\beta_2}{2\gamma_2} \quad (7)$$

This value will maximize ROA_t if $\gamma_2 < 0$.

3.1. Regression model set up

A total of five models were set up, depending on the time span between the independent variables and the dependent variable.

The first model, referred to as Model 12, explains the ROA values in 2012 using the values of the RD/FA and EBIT/RD variables defined in 2012. The second model, referred to as Model 11, explains the ROA values in 2012 using the values of the RD/FA and EBIT/RD variables defined in 2011. Analogously, only the last, fifth model (Model 08) explains the ROA values in 2012 using the values of the RD/FA and EBIT/RD variables defined in 2008.

All the thus-created models are, as a whole, statistically significant at a 1% level; see the following table.

Table 3: Overall characteristics of the models set up

	Model 2012	**Model 2011**	**Model 2010**	**Model 2009**	**Model 2008**
Multiple R	0,4124	0,3305	0,3162	0,2648	0,3761
Multiple R^2	0,1701	0,1092	0,1000	0,0701	0,1415
Adjust R^2	0,1608	0,0991	0,0893	0,0527	0,1046
F-stat.	18,2937	10,8229	9,3889	4,0160	3,8318
p-value	0,000000	0,000000	0,000000	0,003671	0,006292
Std. Error	0,12642	0,13220	0,13383	0,14389	0,15582

Source: Own processing of data from the Amadeus database.

The values of multiple R^2 in the individual models vary from 7.01 to 17.01%; in other words, the models can explain from 7.01 to 17.01% of ROA values using the values of relative R&D expenses with various time spans.

The following table provides details of the individual models. The parameters of these models are distinguished in the same way as the models themselves, e.g. EBIT/RD_12 is a variable of model 12, EBIT/RD_11 a variable of model 11, etc.

Table 4: Details of individual models

Variable	Parameter	t-stat.	p-value	Variable	Parameter	t-stat.	p-value
Constant_12***	0,040800	4,2183	0,000031	Constant_09***	0,050716	3,4954	0,000576
EBIT/RD_12***	0,001951	7,4900	0,000000	RD/FA_09**	0,215699	2,4795	0,013931
RD/FA_12***	0,222569	4,7733	0,000003	EBIT/RD_09***	0,001767	2,6411	0,008876
$EBIT/RD^2$_12*	-0,000004	-1,8619	0,063434	RD/FA^2_09	-0,10116	-1,5014	0,134738
RD/FA^2_12***	-0,107245	-3,7203	0,000231	$EBIT/RD^2$_09*	-1,2E-05	-1,6611	0,098168
Constant_11***	0,051003	5,0696	0,000001	Constant_08	0,012942	0,4326	0,666323
RD/FA_11***	0,190982	4,0820	0,000055	EBIT/RD_08**	0,0074	2,4574	0,015848
EBIT/RD_11***	0,001451	5,4218	0,000000	RD/FA_08**	0,425819	2,6103	0,010545
RD/FA^2_11***	-0,08504	-3,2782	0,001149	$EBIT/RD^2$_08	-7,8E-05	-0,9161	0,361997
$EBIT/RD^2$_11***	-0,000006	-3,5363	0,000460	RD/FA^2_08*	-0,28002	-1,8984	0,060744
Constant_10***	0,037308	3,1892	0,001560				
RD/FA_10***	0,229331	3,2004	0,001503				
EBIT/RD_10***	0,003511	4,9684	0,000001				
RD/FA^2_10 **	-0,121305	-1,9701	0,049644				
$EBIT/RD^2$_10***	-0,000026	-2,7965	0,005462				

Note: *significant at a 10% level, **significant at a 5% level, ***significant at a 1% level
Source: Own processing of data from the Amadeus database.

The parameter for the RD/FA variable, i.e. parameter β_1 (see formula 3), is statistically significant at a 1% level in models 12, 11 and 10, and at a 5% level in models 09 and 08.

The parameter for the RD/FA^2 variable, i.e. parameter γ_1 (see formula 3), is statistically significant at a 1% level in models 12 and 11, at a 5% level in model 10, at a 10% level in model 08 and is not statistically significant at any standard level of significance in model 09.

The parameter for the EBIT/RD variable, i.e. parameter β_2 (see formula 3), is statistically significant at a 1% level in models with the exception of Model 08 where it is significant only at the 5% level.

The parameter for the $EBIT/RD^2$ variable, i.e. the γ_2 parameter (see formula 3), is statistically significant at a 1% level in models 11 and 10, at a 10% level in models 12 and 09, and it is not statistically significant at any standard level of significance in model 08.

The constant, i.e. parameter α_{t-i}, is statistically significant at a 1% level in all models, except for model 08 where it is not statistically significant at any standard level of significance. The value of the constant varies from 16.51 to 65.05% of the average ROA value in the sample**.**

3.2. Theoretical values of ROA-maximizing R&D expenses

Using relationships (5) and (7), it is possible to deduce the theoretical values of RD/FA_{t-i} and $EBIT/RD_{t-i}$ that result in maximization of the ROA_t value. They can provide a theoretical maximum value of ROA_t corresponding to these indicators RD/FA_{t-i} and $EBIT/RD_{t-I}$ (see Table 5).

Table 5: Theoretical values of ROA-maximizing EBIT/RD and RD/FA under evaluation.

Variable	Value	Variable	Value	ROA**
EBIT/RD_12	243,8	RD/FA_12	1,04	0,3942
EBIT/RD_11	120,9	RD/FA_11	1,12	0,2460
EBIT/RD_10	67,52	RD/FA_10	0,95	0,2642
EBIT/RD_09	73,63	RD/FA_09	1,07*	0,2307
EBIT/RD_08	47,44	RD/FA_08	0,76*	0,3503

*calculated using parameters that were not statistically significant
**theoretical values of ROA_t in application of ROA maximizing EBIT/RD and RD/FA

The actual value of ROA in 2012 ranged from 0.541 to 0.711. The median value was 0.0681. Only the top 10, resp. 5% of the surveyed enterprises reached values higher than 0.207, resp. 0.262.

Under optimal R&D expenses (measured by EBIT/RD and RD/FA), it is theoretically possible to achieve ROA values in the range of 0.230 to 0.394. However, it should be noted that further growth in R&D expenses would have led to a decrease in ROA.

A comparison of the actual and theoretical values shows that there are enterprises (approximately 5% of enterprises in our sample) that take advantage of this potential. Their R&D expenses are, in terms of the impact on ROA, optimal. Remaining 95% of the companies below this theoretical limit.

4. DISCUSSION

The performance of an enterprise is influenced by a wide range of factors, including innovation activity. One of the methods of its evaluation is to use the expenses expended on that activity in the period in question. Innovation intensity can be evaluated by referring these expenses to some other variable. The potential benefits of innovation activity can be expected particularly in future periods.

The research performed examined the effect of R&D expenses in the period 2007 to 2012 on the values of the return on assets (ROA) of enterprises for the year 2012. It was ascertained that a statistically significant correlation can be found between the values of R&D expenses/fixed assets ratio, or EBIT/R&D expenses, defined in the period 2007 to 2012 and the return on assets value for 2012.

The fact that the current return on assets (ROA 2012) in the period 2012 to 2010 can be described using quadratic dependence where the coefficients in the quadratic member (see γ_1 and γ_2) are statistically significant and the negative values suggest that there are R&D expenses degrees that maximize this current ROA value. Thus, our assumption that there is a R&D expenses degree which optimally contributes to performance was confirmed for the above period. In other words, in the period concerned there is an optimum degree of R&D expenses definable for up to 2 years back (i.e. back to 2010). Lower R&D expenses values (compared with the optimum value) represent a reserve in increase in the performance of the enterprise, while higher R&D expenses values decrease this performance and it would be appropriate to reduce them.

Only the coefficients of those linear members of the models (see the β_1 and β_2 coefficients) that have positive values are statistically significant in the period 2009 to 2008. This can be interpreted in that the R&D expenses values in a period dating 3 to 5 years back only increase the current performance while higher R&D expenses values do not decrease current performance in the same period.

A statistically significant constant also exists in all the models, which can be interpreted in that the relevant part of the current ROA under examination (16.51 to 65.05% of the average value from 2012) can be attributed to other factors.

5. CONCLUSIONS

In our paper, we presents the results of an empirical study on the effects of R&D expenses on enterprise's performance.

In order to explain this performance of company (measured by return on assets ROA, one of the typical enterprise performance indicator) in terms of innovation strategies, we considered the quadratic model. Our representative sample of European manufacturing companies contains mostly medium and large-sized companies.

With the help of statistical model we found evidence on the positive impact of past R&D expenses on the return on assets.

Even if the results do not satisfy our expectation, due to relatively weak relationship between R&D expenses and performance, they are in some way consistent with previous studies (Ferrari and La Rocca, 2010; Gerybadze, 2010; Griffith et al., 2006; Barrett and Musso, 2010; Smith, 2006).

Most of previous studies (e.g. Bae and Kim, 2003; Smith, 2006; Zhu and Huang, 2012) utilized for evaluation of relationship between R&D expenses and enterprise performance linear relationship. In other words, they are based on an assumption that higher R&D expenses lead to higher performance. They have proved that innovation activities (measured by R&D expenses) is consistent within an enterprise from one year to another. They can be applied in planning within own enterprise. Moreover, the can be used to analyze and predict the innovation levels of competitors.

Ferrari and La Rocca [2010] found the relationship between performance (measured by ROA) and types of innovation and industry structure. Through the linear model they proved that Pavitt's (Pavitt, 1984) taxonomy and the different typologies of innovation are capable of influencing ROA.

Gerybadze [2010] set three types of strategy for large enterprises in mixed combinations: incremental innovation, dynamic growth strategy and industry creation.

Our paper extends previous studies by using quadratic dependence that allows the derivation of the optimal R&D expenses, which maximize the performance on the ROA level. By comparison of the actual and theoretical values we found that more than 95% of companies not fully exploit their innovation potential to performance increasing.

Although, we set theoretical models for innovative activities performance measurement, these models represent just one managerial tool and they should be combined with other techniques to contribute to the optimal decision making. Moreover, further research has to focus on stability of derived values in long term period and also the possibility of application of this approach for small enterprises.

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REFERENCES

Apergis, N, Eleftheriou, S. and Payne J.E. 2013. The relationship between international financial reporting standards, carbon emissions, and R&D expenditures: Evidence from European manufacturing firms. *Ecological Economics*, 88, 57-66.

Bae. S. and Kim, D. 2003. The effect of R&D investments on market value of firms: evidence from the U.S., Germany, and Japan. *Multinational Business Review*, 11(3), 51-75.

Barrett, Ch. and Musso, Ch. 2010. *R&D after the crisis: McKinsey Global Survey results*. McKinsey. Available from:

http://www.mckinsey.com/insights/operations/r_and_38d_after_the_crisis_mckinsey_global_survey_results [accessed 28 June 2014].

Brusoni, S., Cefis, E. and Orsenigo, L. 2006. Innovate or die? A critical review of the literature on innovation and performance. *KITeS Working Paper No. 179,* 1-30.

Carayannis, E.G. and Provance, M. 2008. Measuring firm effectiveness: towards a composite innovation index built on firm innovative posture, propensity and performance attributes. *International Journal Innovation and Regional development,* 1(1), 90-107.

Cefis, E. and Ciccareli, M. 2005. Profits differentials and innovation. *Economics of Innovation and New Technology,* 14(1/2), 43-61.

Chauvin, K. and Hirschey, M. 1993. Advertising, R&D expenditures and he market value of the firm. *Financial Management*, 22(1), 128-140.

Czarnitzki, D and Kraft, K. 2010. On the profitability of innovative assets. *Applied Economics,* 42, 1941-1953.

Ferrari, M. and Rocca, L.L. 2010. Innovation and performance: Some evidence from Italian firms. In: Epstein, M. et al., eds. *Performance measurement and management control: Innovative concepts and practices.* Bradford: Emerald Group Publishing, 115-141.

Gault, F. 2013. *Handbook of innovation indicators and measurement.* Cheltenham: Edward Elgar Publishing.

Gerybadze, A. 2010. R&D, innovation and growth: Performance of the world's leading technology corporations. In: Gerybadze, A. et al., eds.*Innovation and international corporate growth.* Berlin: Springer, 11-30.

Griffith, R., Huergo, E., Mairesse, J. And Peters, B. 2006. Innovation and productivity across four European countries. *Oxford Review of Economic Policy*, 22(4), 483-498.

Lazzarotti, V., Manzini, R. and Mari, L. 2011. A model for R&D performance measurement. *International Journal of Production Economics,* 134, 212-223.

Marshall, W. 1980. Discussion of the economic effects of involuntary uniformity in the financial reporting of R&D expenditures and accounting for research and development costs: The impact on research and development expenditures. *Journal of Accounting Research,* 18, 84-90.

Neely, A. 2005. The evolution of performance measurement research. Development in the last decade and a research agenda for the next. *International Journal of Operations & Production Management,* 25(12), 1264-1277.

OECD. 2002. Frascati manual. Paris: OECD.

OECD. 2005. Oslo manual, guidelines for collecting and interpreting innovation data. Paris: OECD.

Pavitt, K. 1984. Sectoral patterns of technical change: Towards a taxonomy and a theory. *Research Policy*, 13, 343-373.

Smith, R. 2006. Modelling R&D investments. *Research Technology Management,* 49(6), 16-22.

Szewczyk, S., Tsetsekos, G. and Zantout, Z. 1996. The valuation of corporate R&D expenditures: evidence from investment opportunities and free cash flow. *Financial Management,* 25(2), 105-110.

Tohumcu, Z. and Karasakal, E. 2010. R&D project performance evaluation with multiple and interdependent criteria. *IEEE Transactions on Engineering Management,* 99, 1-14.

Valenta, F. 1969. *Tvurci aktivita-inovace-efekty*. Prague: Velryba.

Valenta, F. 2001. *Inovace v manazerske praxi*. Prague: Velryba.

Youndt, M., Subramaniam, M. and Snell, S. 2004. Intellectual capital profiles: an examination of investments and returns. *Journal of Management Studies,* 41(2), 335-361.

Zhu, Z. H. and Huang, F. 2012. The Effect of R&D Investment on Firms Financial Performance: Evidence from Chinese Listed IT Firms. *Modern Economy*,3 (1), 915-919.

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