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ORGANIZATIONAL AMBIDEXTERITY, PERFORMANCE AND KNOWLEDGE MANAGEMENT: EMPIRICAL EVIDENCE FROM THE ENERGY AND PHARMACEUTICAL SECTORS

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ORGANIZATIONAL AMBIDEXTERITY, PERFORMANCE AND KNOWLEDGE MANAGEMENT: EMPIRICAL EVIDENCE FROM THE ENERGY AND PHARMACEUTICAL SECTORS

Purpose: Several types of organizational ambidexterity proposed in the relevant literature were quantitatively analyzed in the paper. Considered ambidexterity strategies was justified by different types of knowledge management that may be applied in each case for their successful implementation. Knowledge Management is considered an institutional system which is in place in almost all companies but used differently. Yet effective knowledge management is a major driver of sustainable company development, it's among the essential ingredients for effective use of companies knowledge and competencies as well as for strategy development and competitive intelligence.
Design/methodology/approach: Empirical analysis of different ambidexterity strategies for the energy and pharmaceuticals sectors was provided. Data envelopment analysis (DEA) method was applied to estimate organizational ambidexterity using innovation performance measures. The DEA score based on entrepreneurial intensity input and short term and long term performance acted as a proxy for organizational ambidexterity. Sustainability and product ambidexterity were also considered as the key factors of organizational ambidexterity.
Results: Estimations strongly associate organizational ambidexterity with efficiency of the company in both sectors examined here. Positive relation between performance and organizational ambidexterity for energy sector were discovered. At the same time orientation towards sustainability disrupts performance of pharmaceutical companies. The analysis provided in the paper provides indication for coupling knowledge management and organizational ambidexterity.
Originality/value: The new approach for measurement of organizational ambidexterity using DEA is proposed in the paper. Different strategies including product ambidexterity and sustainability are estimated and their performances are compared. Knowledge management practices are used to justify the choice of ambidexterity strategies.

Keywords: organizational ambidexterity, entrepreneurial intensity, innovation performance, knowledge management, sustainable development, Data Envelopment Analysis

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1. Introduction

Traditional value creation approaches no longer address all the emerging challenges for modern enterprises fully. Over the last two decades Entrepreneurial intensity (EI) has emerged a key issue of strategic management along with all types of innovation activities (Morris and Sexton, 1996). EI refers to different strategic decisions including product innovation, process innovation, expansion to new markets and business model innovation.

Preparing related decisions however requires well-structured and systematic information collection and analysis. This in turn forms part of the core features of company knowledge management. Knowledge management (KM) should not be confused with information technology: IT is an important enabler, for example in providing document management solutions, but knowledge management is a far wider subject. It represents an active approach to identifying, using and enhancing the tacit as well as the explicit and embodied capabilities and experiences of an organization. It represents a systematic and organized attempt to use knowledge within an organization to fulfil organizational objectives and enhance its value to stakeholders (*organizational KM*) (Becerra-Fernandez 2001). This could be enhanced by transforming its ability to store and use information, and developing the assets of the organization, new products and processes (*technological KM*) (Hit et al 2000; Gold and Arvind Malhotra 2001; Bonifacio et al 2000). In addition to organizational and technological KM literature often quotes *ecological KM* which is more targeted on natural resources and ecological developments over time for a completely different purpose than organizational and technological KM (Berkes et al 2000; Moller et al 2004; Usher 2000). The scope of ecological KM is in monitoring of ecological and natural resources and development instead of economically viable outcomes which is the case for technological and organizational KM.

In general KM requires that the entire organization is aligned to support the generation and sharing of knowledge (Kakabadse et al 2003). From the KM main basic duties descriptions it becomes that KM fulfils a supporting role for company innovation activities thus for long term corporate strategic development.. However innovation isn't a one-time event but requires a continuous efforts to build and maintain a healthy innovation project pipeline which has the potential of exploitation and economic value generation. Still innovation is often related and tied people and tacit knowledge initially which makes KM an important asset for companies who need have an inherent interest in getting less dependent on individual people and their knowledge in order to safeguard a consistent innovation stream. In this regard KM is considered an approach which supports innovation activities in a broader sense by codifying and storing information and knowledge as to the extent possible and to provide people involved in innovation activities a support tool to use in daily operations.

Furthermore KM and it's relevance to innovation can also be viewed in light of the organizational ambidexterity (OA) which is an organization's ability to pursue several competing objectives at the same time (Adler et al., 1999; Porter, 1996). For example, the firm can be involved in process and product innovation simultaneously, distributing resources among them. This means that business processes can be made more efficient while also finding more customers and exploring new market niches with new products. In this case KM can serve as a necessary ingredient of such strategy allowing to use information about core products for development and distribution of new ones

The framework of organizational ambidexterity was introduced by March (1991). March considered exploitation and exploration activities of firms and the competition between them. Exploitation activities incrementally and relatively quickly improve existing technologies and business processes aiming at rising efficiency and risk reduction. On the contrary, March posited that exploration refers to new opportunities in the distant future, increasing uncertainty and room for managerial flexibility. Exploration is close to the real-option approach in strategic management practice (e.g. Dortland et al., 2014). Innovativeness and risk-taking depend on the success of previous innovative activities. An optimal balance or trade-off between exploitation and exploration determines organizational ambidexterity.

Developing March's ideas, Gupta et al. (2006) argued that exploration and exploitation are mutually enhancing for organizational performance. Many researchers (Gibson and Birkinshaw, 2004; He and Wong, 2004; Lubatkin et al., 2006; Raisch et al., 2009; Simsek, 2009) agree with them and empirically show that organizational ambidexterity is beneficial for a firm's efficiency. However, some studies (Atuahene-Gima, 2005) documented a negative effect. Following March's approach and the above literature, in this paper we study the impact of OA and distinguish between the short-term and long-term effects for firms.

There are many approaches to measure the impact on efficiency. It can be estimated using organizational performance measures (Murphy et al., 1996). Short-term effects can be discovered by looking at accounting performance measures such as profit margins, return on assets, return on investment, etc. Narrower product performance can be revealed through sales growth and market share. More sophisticated back-looking measures, including total shareholder return, economic value added and etc. are value-based and take into account shareholders' risks. Financial market measures such as trailing EPS and market capitalization are forward-looking, but capture mostly short -term effects according to investors' expectations. Richard et al. (2009) distinguish mixed measures: cash flow divided by the number of shares (CF per share), market-to-book value, and Tobin's Q. Maditinos et al. (2011) highlight the plausible properties of market-to-book value compared to financial accounting and market measures because it is not only forward-looking but can also be a proxy for future growth opportunities.

The impact on organizational performance can be also considered from the perspective of innovative activities and EI. Then such impact is called innovative performance which is a measure of EI efficiency. Griliches (1981) suggested that product and process innovation have a positive effect on the long-term operating performance and should increase the market value. Empirical evidence has showed a positive impact of innovations measured via patent indicators on value and long-term performance (Bessler and Bittelmeyer, 2008). R&D expenditures (Coombs and Bierly III, 2006), patent counts, patent citations (Narin et al., 1987), new product announcements (Iversen et al., 2007) are useful proxies for innovativeness. Coombs and Bierly III (2006) underline the lagged relationship between R&D expenses and patents, since patents are obtained at the earlier stages of R&D projects. Narin et al. (1987, p. 144) stated that the number of patents is "a better indicator of corporate commitment to pursue innovation than the actual amount of innovation". Hagedoorn and Cloodt (2003) argued that a one-indicator approach is more appropriate for high-tech industries, although pharmaceuticals need a composite indicator to capture the multidimensionality of innovative performance.

Organizational effectiveness may go beyond organizational and innovative performance to include external measures that are not associated with economic valuation for traditional stakeholders: shareholders, managers, or customers (Richard et al., 2009). Such external measures may be corporate social responsibility. Long-term efficiency can be related also to sustainable development. This idea is reflected in the relevant literature. For example, Chen et al. (2014) conducted interviews with managers and showed a positive effect of sustainability goals on organizational and innovative performance. Du et al. (2013) also stressed organizations' new focus on sustainable development.

The relationship between organizational ambidexterity, entrepreneurial intensity, sustainable development, organizational performance and knowledge management are well studied. However, we note the lack of quantitative estimates of organizational ambidexterity in the literature as well as insufficient and controversial empirical evidence of the effects of organizational ambidexterity, which mostly comes from interviews and questionnaires. This study aims to fill some of those gaps.

Based on the related literature, we may conclude that OA is industry specific. That is why we considered companies from two major sectors. Our choice of the energy (mainly oil and gas) and pharmaceutical sectors was justified because ambidexterity and sustainability goals can be easily traced in these industries. We develop a methodology and propose three different approaches to assess OA based on quantitative estimates. The consideration of exactly three approaches was

inspired by different types of knowledge management which each of them may require, namely: organizational, technological and ecological.
We use empirical evidence to estimate the OA and its relationship to performance measures. Based on our empirical results, we discuss what type of OA has a more plausible impact on long-term efficiency and consider some implications for small and medium enterprises (SMEs).

2. Approaches to measuring Organizational Ambidexterity in Energy and Pharmaceuticals

The relevant literature examines different types of OA. We consider only three approaches here using the reasoning that comes from different KM solutions that may be applied in each case. OA can be characterized by pursuing simultaneously the following distinct goals: short-term growth vs. value growth (first type). In this case company's strategy should include organizational knowledge management. The second type of OA can be pursued by increasing the share of core products vs. share of new disruptive products. In this case the technological KM will help to use information about core product technologies and technological processes for development of new products. Finally profitability vs. sustainability could represent the third type of OA. In third case KM will help to avoid violation of sustainable goals chasing higher profits. We do not claim here that all three types of KM should not be combined together along with different types of OA in company's strategy but we insist that all them are necessary for realization of mentioned organizational goals and help to illustrate differences between considered strategies.
We consider each type of OA applied to the energy and pharmaceutical sectors.

2.1. Short-term and long-term efficiency

The first approach to measure OA is developed based on the explorative-exploitative approach (He and Wong, 2004; Junni et al., 2013; Uotila et al., 2009). Junni et al. (2013) summarized the measurement approaches to OA. Two measures of performance, namely profitability and growth were considered. A positive relationship between OA and performance was only revealed for growth indicators. They confirmed that this result is industry-specific, especially for high-tech sectors and service companies.
He and Wong (2004) noticed that exploration and exploitation reflects different firm behaviour. They provided empirical evidence to show that the interaction between explorative and exploitative innovation strategies is positively related to the rate of sales growth and that the relative imbalance (absolute difference) between explorative and exploitative innovation strategies is negatively related to the rate of sales growth. Uotila et al. (2009) discovered an inverted-U shaped relationship between a firm's relative exploration orientation and its financial performance measured as Tobin's Q. The effect was stronger in R&D-intensive industries. Gibson and Birkinshaw (2004) pointed out two types of OA, namely contextual ambidexterity (the behavioural capacity to adapt) and structural ambidexterity (the ability to pursue two competitive objectives).
Based on the above literature, we consider two goals that a company strives to achieve: revenue growth and market-to-book ratio (MB). Revenue growth represents a short-term goal while MB is an indicator of longer term projected efficiency of a company according to investor's expectations. Elaborating concept of organizational KM we argue that knowledge within an organization helps to achieve short-term organizational objectives and at the same time increase its shareholders' value (Bontis et al 1997; Chase 1997; Civi 2000; Wen Chong et al 2000.
To estimate the organizational ambidexterity, the efficiency of pursuing both goals was assessed using data envelopment analysis (DEA). According to the DEA method, we identify the best practice within a set of comparable decision makers, which form an efficient frontier and measure the level of efficiency of non-frontier companies according to it (Cook and Seiford, 2009). As a result of DEA estimation, each company receives an efficiency score relative to other observations in the sample. Each observation receives efficiency score within [0;1]. The

score is obtained by maximization of production function (i.e. outputs) with the constrained (given) inputs.
The considerable advantage of DEA stems from the non-parametric nature of efficient frontier, i.e. the functional form of the relationship does not have to be specified. By allowing the relationship between the variables to be based on their observed nature, the DEA method means that inadequate assumptions can be avoided. The DEA model retains natural heterogeneity, taking into account differences in strategies and management practices (Richard et al., 2009). DEA is a multiple input–multiple output method and may account for multidimensionality. DEA intends to measure efficiency of resource utilization and/or employed technologies within organizations (Charnes et al., 1978). The main limitations of DEA method are lack of data and the need for additional constraints in the presence of competition (e.g. price of resources)
We consider EI as an input which reflects a company's strategic decisions. Performance measures, represented by short–term revenue growth and market to book ratio are outputs for the DEA method. OA is measured as the DEA score and represents the ability of a company to effectively pursue short-term and long-term innovative performance goals simultaneously. A high DEA score does not necessarily mean that the company is efficient or performs well. It means that the company has ambidexterity motives and efficiently distributes resources and entrepreneurial activities between short-term and long-term goals. In both energy and pharmaceutical sectors, the first approach can be applied similarly, which is not the case for the second type of OA considered below.

2.2. Share of core and disruptive products

Voss and Voss (2013) studied SMEs and discovered several types of OA. The more general type is cross-functional ambidexterity across product and market domains. Product ambidexterity simultaneously explores new product capabilities and exploits current product capabilities, whereas market ambidexterity simultaneously explores new customer markets and exploits current customers. O'Reilly and Tushman (2008) also considered two domains for exploitation and exploration: product and market. Shapiro (2006) suggested that the share of revenues from new products does not measure the degree or age of innovation, while the share of revenue from new platforms is a more appropriate measure of innovation. Due to possible difficulties in estimating such revenues, we choose the more traditional product ambidexterity for the second type of OA. Product ambidexterity is the share of disruptive products in the overall activities of a firm. Despite some disadvantages of such an indicator, it means we can calculate directly the performance of disruptive business segment compared to core activities.
For the energy sector, we indicate two competing activities: traditional or core business (oil and gas extraction, refining and distribution) and renewables. The two objectives compete for companies' resources, customers, and markets. Success in one activity will disrupt the other. An emerging trend of transition from fossil fuels to renewable energy (Arens et al., 2011) is impairing the traditional source of revenue for companies in the energy sector. But with good technological KM competition between different divisions will not harm the company and its financial and strategic goals may be achieved (Kakabadse et al 2003, Argyres and Silverman 2004).
To estimate OA, we compare R&D expenditures in the traditional line of business, i.e. related to oil and gas exploration, with that in the development of renewable energy sources. We postulate that KM is integral part of R&D and at least KM features dedicated to R&D activities are included in the overall R&D expenditures. The choice of R&D expenditure for estimating the share of disruptive products can be justified by the large proportion of oil and gas companies' resources attributed to renewables on the development stage which is not yet reflected in related revenue.
For pharmaceutical companies, we analyze two competing lines of business: medicine for treatment and vaccines as technology response to healthcare priorities (Kaminskiy et al., 2013). The organizational ambidexterity in this case is related to the different business objectives

underlying each activity. A vaccine is considered effective if it prevents certain diseases and, therefore, limits the ultimate demand for treatment products. In the case of pharmaceutical companies, we use the share of revenues from vaccines as a proxy for OA. A revenue-based measure is more suitable for the pharmaceutical sector as R&D activities may be connected with both the considered objectives.

2.3. Profitability vs. sustainability

As mentioned earlier, the long-term goals of an organization can be related to sustainable development (Chen et al., 2014; Du et al., 2013). The Quintuple Innovation Helix approach (Carayannis and Rakhmatullin, 2014) suggested that innovation should be considered in a broader meaning of the natural environments of society, which are closely tied to sustainable development goals. In that sense, OA can reflect the ability to be efficient in current operations and simultaneously adaptive and flexible to changes in the environment (Chen et al., 2014). A so-called green shared vision (Larwood et al., 1995) and green absorptive capacity (Cohen and Levinthal, 1990) may explain exploration and exploitation types of organizational ambidexterity related to sustainable development. Moreover, Chen et al. (2014) empirically showed that OA increases green radical and incremental innovation performance.

The above arguments support the third approach to measuring organizational ambidexterity, namely one related to companies' sustainable strategy. The two competing objectives are profitability and sustainability. The sustainable development of a company implies a shift to green technologies, the introduction of new green products, energy safety, and efficiency. Sustainability goals may require appropriate ecological KM to avoid negative risks associated with them.

In order to estimate the sustainability of oil and gas companies, we use the Green ranking index, provided by *Newsweek*.[4] Each year, they publish a list of the top 500 green companies in the world. The methodology of rank calculation includes 8 indicators (**Ошибка! Источник ссылки не найден.**).

We suggest that a company's high green rank means that besides traditional profitability goals it pursues sustainable goals and, hence, its OA is also higher. The green rank is an adequate measure for OA in the oil and gas sector because several of its components directly address the most important industry issues. The green rank can be also used in the pharmaceutical sector. However, in the latter case its components are not directly related to major revenue sources and costs. That is why we used one more approach for capturing the sustainable motives in the pharmaceutical sector. We also considered pharmaceutical companies' involvement in innovative financing for development.

Innovative financing for development is related to new sources of funding, new methods of fund-raising and disbursement of funds,] and the adoption of existing mechanisms in new markets in support of international development (World Bank, 2010; OECD, 2014). Innovative financing is usually used in sectors with high social impact but low financial profitability, such as healthcare, education, and environment protection. Since 2015, innovative financing is related directly to the global sustainable development goal to promote global health and finance immunization programmes in developing countries (United Nations, 2015). We reviewed several vaccination programmes, which aim to create collaborations between manufacturers, suppliers, and developers of vaccines in order to prevent the spread of disease in epidemic-prone countries. We argue that companies participating in such innovative financing initiatives pursue both profitability and sustainability goals and express organizational ambidexterity.

The three types of OA we analyze here represent three different motives which influence strategy company's choice . We also argue that organizational, technological and ecological KM may help OA strategies to succeed. . We now illustrate these three approaches to OA using

[4] Green ranking 2015: http://www.newsweek.com/green-2015

empirical data from both the energy and pharmaceutical sectors and attempt to evaluate which approach is more beneficial for a company.

3. Empirical evidence from the energy sector

We collected data on energy companies from two databases, corporate annual reports, financial statements, and sustainability reports. We took data on revenues, R&D expenditures, and capital expenditures from 2007 to 2015 from COMPUSTAT. The Orbit database provided information on the number of patent applications during the same period. We used the Green ranking for the year 2015 as a measure of sustainability. The companies were chosen according to their SIC codes: SIC code 13 – "Oil and gas extraction" for the energy sector. The sample was limited to companies with last reported assets higher than US$1,000 million to exclude start-up firms. The final sample consisted of 94 energy companies.

3.1. Short and long term efficiency

As a proxy for short-term organizational performance for the first approach to OA, we estimated the revenue growth rate based on annual revenue data. To account for long-term efficiency, we employed market-to-book value ratio.

Three year moving averages (MA) for six periods starting 2007 were calculated in order to offset annual data fluctuations. The change of revenue growth rate was calculated based on MA values:

$$(1)\ \Delta Revenue_i = \frac{Rev_{2008+i} - Rev_{2007+i}}{Rev_{2007+i}} - \frac{Rev_{2007+i} - Rev_{2006+i}}{Rev_{2006+i}}$$

Using this data, we conducted data envelopment analysis (DEA) with two specifications:

$$(2)\ Outputs: \Delta Revenue, MB\ ratio;\ Inputs: \frac{Capex}{Revenue}, \ln \Delta\ Patent\ count.$$

$$(3)\ Output: \Delta Revenue;\ Inputs: \frac{Capex}{Revenue}, \ln \Delta\ Patent\ count.$$

Both specifications were tested as output-oriented models. The results of the DEA tests are efficiency scores for each company in the sample that show relative efficiency in pursuing defined outputs by employing the given resources or inputs (Hoff, 2007). We considered the DEA score as a proxy for the OA of companies in the energy sector. In order to evaluate the impact of OA on the company's long-term performance, we calculated the correlations between the MB and DEA scores as well as the average MB for the score above and below the median 0.0549. The correlation between market-to-book value ratio and organizational ambidexterity as measured by DEA efficiency score is 15.08% (Table).

Table 1. Empirical results for the energy sector: OA measured as DEA efficiency score.

Indicator	Correlation with market-to-book value ratio	Average market-to-book value ratio
DEA efficiency score (2-output model)	15.08%	2.5958
Score > 0.05		3.0491
Score < 0.05		2.1426

To test the results of DEA impact on MB, we conducted a regression analysis according to the following model:

$$(4)\ MB_i = c + \beta_1 DEA\_score_i + \beta_2 \ln(assets_i) + \beta_3 \ln(\Delta\ patent\ count_i)$$

where: DEA_score stands for DEA efficient score for each company in the sample; $\ln(assets_i)$ is a natural logarithm of assets; and $\ln(\Delta\ patent\ count_i)$ indicates the log change in companies' patent count. We included patent statistics and assets as control variables to allow for company

innovation performance and size. The model was tested using panel least squares regression with fixed cross-section effects and random period effects as specification with highest explanation power measured by R-squared. The specification was supported by the Hausman test and Likelihood ratio test at the 1% significance level.
We found that OA as measured by DEA efficiency score has a significant positive impact on market-to-book value (Table 2).

Table 2. Regression statistics for DEA score: the energy sector

Dependent Variable: *MB*
Method: Panel EGLS (Period random effects)
Periods included: 5
Cross-sections included: 94
Total panel (balanced) observations: 470
Swamy and Arora estimator of component variances

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Intercept	-12.3826	6.6354	-1.8661***	0.0628
DEA score	4.0005	2.3101	1.7318*	0.0841
ln (patent count)	3.2664	1.2306	2.6543***	0.0083
ln (assets)	1.5030	0.6957	2.1606**	0.0314
	Effects Specification			
			S.D.	Rho
Cross-section fixed (dummy variables)				
Period random			0.4229	0.0283
Idiosyncratic random			2.4804	0.9717
	Weighted Statistics			
R-squared	0.7125	Mean dependent var		2.5958
Adjusted R-squared	0.6385	S.D. dependent var		4.1162
S.E. of regression	2.4749	Sum squared resid		2284.6407
F-statistic	9.6288	Durbin-Watson stat		1.1390
Prob(F-statistic)	0.0000			
	Unweighted Statistics			
R-squared	0.7091	Mean dependent var		2.5958
Sum squared resid	2319.2708	Durbin-Watson stat		1.1701

* *- significant at the 10% level*
** *- significant at the 5% level*
*** *- significant at the 1% level*

The regression results are consistent with the evidence obtained by correlation analysis for the energy sector (Table).

3.2. Share of core and disruptive products

To measure the second type of OA, we calculated the share of renewables of total R&D expenditures. We collected data on R&D expenditures from corporate reports of energy companies included in the Top 500 Green companies ranked by *Newsweek*. The sample consist of 45 energy firms, of which 19 companies conducted R&D related to renewables in the last reported year.
The correlation between market-to-book value ratio and OA as measured by the share of total R&D expenditure is 19.64% (Table). There is a slight positive relationship between product ambidexterity and market-to-book value. Firms with higher OA tend to be seen as more effective by the market in the long-term.

Table 3. Empirical results for the energy sector: OA measured as product diversification

Indicator	Correlation with market-to-book value ratio	Average market-to-book value ratio
OA (share of renewables R&D)	19.64%	1.7224
OA = 0		2.1635
OA > 0		1.3860

3.3. Sustainable development

For the third approach, we used a sample of 45 energy companies that were included in the list of the Top 500 Green companies. The correlation between market-to-book value ratio and degree of sustainability as measured by the Green rank is 19.14% (Table).

Table 4. Empirical results for the energy sector: OA measured as Green ranking

Indicator	Correlation with market-to-book value ratio	Average market-to-book value ratio
Green rank	19.14%	1.4724
Rank > 40		1.7047
Rank < 40		1.2866

Therefore, sustainable energy companies tend to be seen as more effective by the market in the long-term.

4. Empirical evidence from the pharmaceutical sector

We used the same information sources as mentioned above for the pharmaceutical sector. The companies were sampled according to their SIC codes: SIC code 283 – "Drugs" for the pharmaceutical industry. The same restrictions on companies' size were applied as for the energy sector. The sample includes 111 pharmaceutical companies.

4.1. Short and long-term efficiency

As in the energy sector, the correlations between the MB and DEA scores as well as the average MB for the DEA score above and below the median 0.2118 were calculated (Table). The correlation between market-to-book value and OA measured by DEA efficiency score is 26.24%.

Table 5. Empirical results for pharmaceutical sector: OA measured as DEA efficiency score.

Indicator	Correlation with market-to-book value ratio	Average market-to-book value ratio
DEA efficiency score (2-output model)	26.24%	6.1473
Score > 0.21		8.1658
Score < 0.21		4.1360

Thus, ambidextrous companies in terms of their long-term strategic orientation tend to be slightly more efficient compared to the average industry performance.

To test the OA impact on MB, we again conducted regression analysis with slightly different specification of control variables:

$$(5)\ MB_i = c + \beta_1 DEA\_score_i + \beta_2 \ln(revenue_i) + \beta_3 \ln(\Delta\ patent\ count_i)$$

OA as measured by DEA efficiency score had a significant positive relationship with market-to-book value ratio at the 10% significance level (Table). The regression statistics are consistent with the evidence obtained through correlation analysis.

Table 6. Regression statistics for DEA score: the pharmaceutical sector

Dependent Variable: *MB*
Method: Panel Least Squares
Periods included: 5
Cross-sections included: 111
Total panel (balanced) observations: 555

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Intercept	131.6968	30.7792	4.2788*	0.0000
DEA score	11.9763	7.1802	1.6680*	0.0960
ln (patent count)	27.6960	8.9645	3.0895***	0.0021
ln (revenue)	-17.2475	4.0615	-4.2466***	0.0000
	Effects Specification			
Cross-section fixed (dummy variables)				
Period fixed (dummy variables)				
R-squared	0.6795	Mean dependent var		6.1473
Adjusted R-squared	0.5937	S.D. dependent var		26.7755
S.E. of regression	17.0679	Akaike info criterion		8.6985
Sum squared resid	127303.8493	Schwarz criterion		9.6167
Log likelihood	-2295.8244	Hannan-Quinn criter.		9.0572
F-statistic	7.9180	Durbin-Watson stat		1.3535
Prob(F-statistic)	0.0000			

** - significant at the 10% level*
**** - significant at the 1% level*

4.2. Share of core and disruptive products

To measure OA for two competing business segments of pharmaceutical companies, drugs versus vaccination products, we calculated the share of vaccines sales of total revenue. We restricted the sample to 32 firms included in the Newsweek Green Ranking, out of which 13 companies produced vaccines in the last reported year.

The correlation between market-to-book value and OA as measured by the share of vaccines in total revenue is 30.46% (Table).

Table 7. Empirical results for the pharmaceutical sector: OA measured as share of vaccines of revenue

Indicator	Correlation with market-to-book value ratio	Average market-to-book value ratio
OA (Share of vaccines revenue)	30.46%	5.5900
OA = 0		5.5747
OA > 0		5.1824

For pharmaceutical companies, the OA impact on company performance is mixed.

4.3. Sustainable development and OA

For the third approach, we again used a sample of 32 pharma companies that were included in the Top 500 Green Ranking. The correlation between market-to-book value ratio and degree of

sustainability orientation as measured by the Green rank is -45.27% (Table). Therefore, sustainability-oriented pharmaceutical companies tend to be less effective in the long-term.

Table 8. Empirical results for the pharmaceutical sector: OA measured as Green ranking

Indicator	Correlation with market-to-book value ratio	Average market-to-book value ratio
Green rank	-45.27%	5.5900
Rank > 40		4.1463
Rank < 40		8.6584

To further verify the estimates of the third approach to OA in the pharmaceutical industry, we decided to include innovative financing initiatives in our review as a direct indicator of the participation of pharma manufacturers in sustainable initiatives. We used a dummy variable for OA proxy, which equalled 1 if the company participates in at least one of the reviewed innovative financing initiatives and 0 otherwise. The following major initiatives were taken into consideration: GAVI the Vaccine Alliance[5]; Medicines for malaria venture[6] (MMV); and Medicines patent pool (MPP).[7] We used a sample of 32 companies from the list of Top 500 Green companies, of which 17 companies participated in at least one of the innovative financing initiatives.

The correlation between market-to-book value ratio and sustainability orientation as measured by the dummy for innovative financing is -47.92% (Table).

Table 9. Empirical results for the pharmaceutical sector: OA as measured through innovative financing

Indicator	Correlation with market-to-book value ratio	Average market-to-book value ratio
Innovative financing	-47.92%	5.5900
IF = 0		3.3458
IF = 1		7.7608

This result supports the evidence obtained from the Green Ranking indicator above: sustainable pharmaceutical companies tend to be less efficient compared to other firms.

5. Conclusion and implications

We measured the OA of energy and pharma companies using three approaches: (1) pursuing long-term versus short-term innovative performance measured as a DEA two-output efficiency score; (2) the share of disruptive products in a company's activities assessed through the proportion of R&D expenditure; (3) sustainability versus performance of the company, where the Green ranking and participation in innovative financing programmes were used as proxies for sustainable development. We found that all three approaches showed a positive relationship between the OA and a company's market-to-book value ratio for the energy sector. Product diversification and sustainability approaches to OA appeared to be slightly more adequate for estimating the impact of OA on the performance of energy companies. These approaches demonstrate similar results for the energy sector since companies with product ambidexterity conduct R&D in renewables for pursuing sustainable goals. This also allows us to assume that KM is established and used inside the companies. The question in which shape KM is operated

[5] GAVI, the Vaccine Alliance website: http://www.gavi.org/
[6] MMV website: http://www.mmv.org/partnering/product-development-partnership-model
[7] MPP website: http://www.medicinespatentpool.org/

however remains open. Further the impact of KM can't be assessed however there is evidence from the energy sector, namely utilities companies applying KM systems in course of decommissioning of nuclear power plants. KM in these cases demonstrated that working hours and staff assigned to projects and budget risk could be reduced significantly by sharing knowledge and experience. This is achieved by focusing KM on the transfer of personal practice experience within and between projects which allows company internal learning from evidenced experience and respective mutual inspiration and stimulation (Du Plessis 2007).
However, the sustainability orientation of pharmaceutical companies surprisingly had an adverse impact on their performance. In contrast to the oil and gas industry, pharmaceutical companies appear to be more innovative within the core business segment. Market success requires the continual advancement of existing products (for instance, to eliminate registered side effects) as well the research and development of new drugs. Therefore, the product diversification inside the drugs segment should elevate entrepreneurial intensity. Pharmaceutical R&D activities are somewhat different from utilities companies approaches to R&D which is why KM plays a different role in their activities. In the first instance pharmaceutical R&D targets at detecting and testing substances and substances mixes to fight diseases. Therefore a huge amount of data and information are collected in short time during these procedures. Clearly pharmaceutical companies have little interest in testing substances several times for each new indication which is why documentation and storage of knowledge collected over time is an absolute must for pharma R&D. Accordingly the work climate in pharma R&D units and laboratories is featured by continuous information documentation. This is even enforced by the standard clinical trials which are compulsory element of drug development. Thus KM is rightly assumed as essential part of R&D and included in the respective R&D expenditures.
An orientation towards sustainability disrupts the market performance of the pharmaceutical industry. Sustainable development requires the distribution of resources to non-priority segments such as innovative financing initiatives which are dedicated to socially important objectives and do not enhance the financial performance of the company. The mixed results for the impact of OA on performance highly depend on the characteristics of the industry.
Our analyses suggest what may be the most appropriate choice among types of OA in both the energy and pharma sectors. This suggestion can be used to support strategic decision making. This also includes decisions regarding companies' innovation pipelines' thus including scope and shape of KM eventually. Yet KM it's considered a management approach which naturally varies in shape between industrial sectors according to special industry features and also between companies. Thus there is no 'one fits all' approach to KM as for any management concept but indeed it requires dedicated company specific fine-tuning. Our attempt to distinguish between different types of KM was rather methodological and used for illustration of different approaches to OA. Furthermore even once established KM requires continuous refinement and adjustment according to selected project requirements but equally – if not even more – important it needs to take account of employees needs and attitudes. Namely when it comes to highly qualified staff with special skills and competences KM has advantages for these staff members to use but also provides a potential threat if KM systems appear administrative and bureaucratic to them. For companies it's important to recall the meaning of KM and it's potential influence on the companies innovation culture, thus the internal innovation eco-system. This is mainly related to R&D controlling and human resources management which has to assure that the active use of KM isn't perceived as using knowledge and information unilaterally but understand the need to document and store accordingly.

Further data analysis and collection may improve the quality of analysis. A broader view that includes other economic sectors is also important to justify our approaches.
We considered mostly large companies because of a lack of data on SMEs. However, our analysis may be used for developing strategies for SMEs. Many authors have noted that SMEs are biased towards exploration (Zahra et al., 2000; Busenitz and Barney, 1997). Lubatkin et al.

(2006) argued that the ability to pursue exploratory and exploitative goals affects the performance of SMEs.
Cao et al. (2009) noticed that SMEs are relatively constrained by resources due to their small size or scarce operating environments and benefit mostly from achieving a close balance or trade-off between exploration and exploitation. Hence, the first type of OA we considered – one based on a balance of short-term and long-term goals – may be the right choice for general SME strategies. More empirical evidence is needed to support this hypothesis.
Another issue that left beyond the scope of this paper is effect of KM on company performance.
But measuring KM is a more complex undertaking as it comes as a management tool which is difficult to capture in indicator based measurement. Assessing KM requires a broader approach including KM organizational aspects and technical features but also the overarching company culture as an enabler for sharing and documenting knowledge and information. Thus so far no plausible aggregate indicator for the effectiveness and efficiency of KM has been developed and used. Furthermore it's doubtful if measuring and monitoring KM turns out positive for the company innovation climate. There is a clear danger that KM is perceived an intervention into engineers and innovators freedom which is due to the unavoidable because necessary documentation duties. The latter is indeed perceived an administrative burden by company staff and even worse engineers especially fear that their works are monitored continuously. This in turn has potentially negative impact on employees motivation for R&D and innovation.

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Appendix 1. Methodology for calculating the Green ranking (2015)[8]

No.	Indicator	Weight	Description
1	Combined energy productivity	15%	Relation of revenue to total energy consumption for the last three years
2	Combined greenhouse gas (GHG) productivity	15%	Relation of revenue to total GHG emissions for the last three years
3	Combined water productivity	15%	Relation of revenue to total water use for the last three years
4	Combined waste productivity	15%	Relation of revenue to total waste generated net of waste recycled/reused, for the last three years
5	Green revenue score	20%	Share of green revenue generated by products and services that contribute positively to environmental sustainability and societal health, out of total revenue
6	Green pay link	10%	Salaries of senior executives linked to corporate environmental performance (yes/no)
7	Sustainability board committee	5%	Committee at the Board of Directors level related to the sustainability of the company (yes/no)
8	Audited environmental metrics	5%	Audit of last environmental metrics by a third party (yes/no)

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[8] Green ranking 2015, methodology: http://s.newsweek.com/sites/www.newsweek.com/files/newsweek-green-rankings-final-methodology_2015.pdf