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Letter from the Editor

Internationalization & Growth

Being closely linked to each other, internationalization and growth denote two keywords often brought up in these days. Companies in the chemical industry increasingly explore business opportunities beyond their existing business segments, enter emerging markets in fast-growing countries and establish strategic alliances with foreign partners. They understood that going international not only provides a potential source of competitive advantage, but also enables sustainable organizational growth.

Transferring this idea to our journal, we are proud to announce that Mattia Bianchi and Federico Frattini, two of our colleagues from Sweden and Italy, will join the editorial board of the Journal of Business Chemistry. Mattia Bianchi is assistant professor of business administration at the Stockholm School of Economics and research fellow at the Institute of Management, Sant'Anna School of Advanced Studies in Pisa. Federico Frattini is assistant professor at Politecnico di Milano. Both have published several articles on innovation and technology management, international businesses and open innovation in leading journals, such as Journal of Product Innovation Management, Journal of International Business Studies, or California Management Review.

This issue of the Journal of Business Chemistry is to welcome Mattia Bianchi and Federico Frattini as international editors and comprises the following articles from Japan, Finland, Mexico, and Switzerland.

In their research paper "Optimal Ambidexterity and Exploration Valuableness" Osamu Suzuki and David Methe examine how short-term and long-term trade-offs can be balanced in pharmaceutical product development. Their study is based on an empirical analysis of resource allocation patterns for 231 new pharmaceutical products and their economic value. They find that pharmaceutical companies realize a higher exploration degree of valuableness and, thus, an optimal level of ambidexterity by allocating about 1.5 times more resources to exploitative products than to exploratory ones.

Anne Toppinen and Meri Siljama, then, analyze the impact of the Lead Market Initiative (LMI) on bio-based products by means of a qualitative case study. The LMI is an EU initiative and denotes an innovative platform for advancing the knowledge-based bio-economy in Europe. In this study, the researchers seek to identify the main challenges and opportunities of the LMI, to compare these results with other EU initiatives and to clarify if the LMI addresses relevant challenges adequately. They close with a detailed juxtaposition of opportunities and challenges, as well as identify important areas for improvement.

In our practitioner´s section, Álvaro Pedroza Zapata and Sara Ortiz Cantú elaborate on chemical formulation. They present potential sources of information related with technological intelligence in the design of chemical formulations and describe how technology maps can support the integration of technology strategies. Moreover, they provide an overview of relevant scientific databases in in connection with chemical formulation.

In their article "Working Capital Management in the Swiss Chemical Industry" Stefan Seeger, Alwin Locker, and Christian Jergen assess Swiss chemical and pharmaceutical companies with regard to their working capital management. While their analysis reveals that an optimized working capital management may play an important role for a firm's competitiveness, the authors particularly emphasize the commitment and awareness of the management as key drivers of a successful working capital management.

Now, please enjoy reading the second issue of the eighth volume of the Journal of Business Chemistry. We would like to thank all authors and reviewers who have contributed to this new issue. If you have any comments or suggestions, please do not hesitate to send us an email at contact@businesschemistry.org.

Sebastian Kortmann, Executive Editor
(sk@businesschemistry.org)

Journal of Business Chemistry

Research Paper

Optimal ambidexterity and exploration valuableness: balancing short-term and long-term trade-off in pharmaceutical products development

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One of the most challenging resource allocation tasks for managers is to balance short-term and long-term products development initiatives, since exploitative (i.e., short-term focused) resource allocation patterns prevent managers from recognizing the existence or significance of exploratory (i.e., long-term focused) opportunities. Recent research on organizational ambidexterity promises the potential to overcome this trade-off relationship, but they lack clear indications concerning the mix of exploitation and exploration that would result in an optimal degree of ambidexterity. Through the analysis of a unique data set on development resource allocation patterns for 231 new pharmaceutical products, as well as on the economic value of those products, we show that pharmaceutical companies realize a higher exploration degree of valuableness and hence an optimal level of ambidexterity by allocating roughly 1.5 times more development resources to exploitative products than to exploratory ones.

Since the seminal articles by Teece (1982) and Wernerfelt (1984), scholars argue that firm idiosyncratic "resources" are key determinants of firm performance and competitive advantage. Firms are bundle of resources, and those resources per se, as well as how they are combined and deployed, significantly affect firm performance. Consequently, decisions on resource allocation should be a core element of strategic thinking in managing business organizations.

One of the most challenging resource allocation tasks for managers is to balance short-term and long-term products development initiatives. As classic studies on the trade-off relationship between exploitation and exploration (Levinthal & March, 1993; March, 1991) suggest, scholars emphasize that too exploitative (i.e., short-term focused) resource allocation patterns prevent managers to recognize the existence or significance of particular exploratory (i.e., long-term focused) opportunities (Benner & Tushman, 2002; Christensen & Bower, 1996; Gilbert, 2005; Staw, Sandelands, & Dutton, 1981).

This is particularly problematic for global ethical pharmaceutical companies, because the quickly changing competitive situation requires both continuous adjustments to current products and radically new break-through products. The former calls for firms to extensively exploit libraries of existing chemical entities, whereas the latter requires that firms engage in a highly uncertain and lengthy exploration for novel NCEs (new chemical entities). This leads to our basic research question of what is the optimal balance between exploitative and exploratory product development activities for firms?

One of the most notable aspects of today's ethical pharmaceutical industry is increased pressure on firms from competition on price and time to market (Pisano & Rossi, 1994). Pharmaceutical firms apply counter pressure to the market through development of pipelines of potential pharmaceutical drugs. These pipelines of potential pharmaceutical drugs consist of derivatives of existing chemical entities and pipelines that are based on new chemical entities (NCE). An example of a pharmaceutical drug that came from a new chemical entity is Eli Lilly's

Prozac, while its descendents, such as Sarafem is an example of a derivative from the same chemical entity called fluoxetine. Initially, fluoxetine was successfully developed as an anti-depressant (Prozac), and later, Eli Lilly redeveloped it for a different indication of premenstrual dysphoric disorder (Sarafem) upon Prozac's patent expiration.

Often in addressing the pressure, pharmaceutical firms exploit their core competencies by reusing existing chemical entities so that they can quickly launch incrementally new products that are targeted to an existing market. However, too much reliance on exploitation erodes a firm's capability to develop radically new break-through products based on NCEs. One of the unintended consequences of an over reliance on exploitation is that a firm's pipelines grow obsolete and shrink in number due to insufficient exploration for NCEs. This would threaten the long-term survival of the firm unless it found an outside source for NCEs. It could be argued that firms that follow a generic drug strategy are examples of a pure exploitation strategy in that 100 percent of these firms' products come from existing chemical entities and these firms are dependant on other ethical pharmaceutical companies to develop NCEs.

When, on the other hand, firms excessively explore for NCEs, they are likely to be quickly out-competed in the short-term due to not having enough pharmaceutical drugs available for the current market. This would result in the firm gradually be starved of resources, such as cash, thus, threatening sustainable development of identified NCEs which would become marketable in the future. This situation of following a pure exploration strategy is most common in entrepreneurial start-up firms that may be devoting 100 percent of their resources towards some NCE in the hope that it will become a blockbuster drug. These firms must pay close attention to their "burn rate" of current resources, and these must be refreshed from alternative sources such as venture capital markets.

In other words, only through an appropriate balance between exploitation and exploration can pharmaceutical companies sustain their value creation activities of developing innovative new products, since exploitation and exploration inherently preclude each other. Consequently, it is critical to the survival of firms that they find a balance between exploitation and exploration that results in an optimal level of ambidexterity and avoid being doomed to either over-exploit at the risk of losing major innovation opportunities (Levitt & March, 1988), or over-explore not fulfilling the potential of identified innovation opportunities (Anderson & Tushman, 2001). Most major ethical pharmaceutical companies do not follow either a pure exploitation or pure exploration strategy, but attempt to mix their product development activities. These firms are engaging in an ambidextrous strategy in order to maintain a pipeline that provides for both current and future market competition.

Recent advances in our understanding of ambidextrous organizations (Adler, Goldoftas, & Levine, 1999; Gibson & Birkinshaw, 2004; He & Wong, 2004; Kane & Alavi, 2007; Lavie & Rosenkopf, 2006; Lubatkin, Simsek, Ling, & Veiga, 2006; Sheremata, 2000; Siggelkow & Levinthal, 2003; Tushman & O'Reily, 1996; Tushman, Anderson, & O'Reily, 1997; Wang & Li, 2008) provide potential solutions for this dilemma. Organizations can be ambidextrous through such levers as managerial interventions (Tushman, Anderson, & O'Reily, 1997), unique organizational contexts (Gibson & Birkinshaw, 2004), or top management team's behavioral integration (Lubatkin, Simsek, Ling, & Veiga, 2006) in that they can exploit, as well as explore at the same time.

Unfortunately, the work of these scholars has opened an important question that has yet to be clarified; that is, what is the optimal balance of resource allocation between exploitative and exploratory initiatives. Considering the fact that most organizations pursue both exploitation and exploration to a certain extent (i.e., perfectly exploitative or exploratory resource allocation is unrealistic), this lack of understanding on the optimal resource allocation is problematic. This is because although managers know pursuing both exploitation and exploration is important for ensuring favorable innovation performance, it is unclear whether they should increase or decrease resources allocated to exploitative (or, exploratory) initiatives. Therefore, as we noted above, our primary research question is what is the optimal balance of resource allocation between exploitative and exploratory initiatives. By answering this question, we will make more explicit a guideline by which managers can adjust their current resource allocation between exploitative and exploratory pharmaceutical product development initiatives and develop an optimal level of ambidexterity in product development activities.

Research on ambidextrous organizations also predominantly focuses on one aspect of performance benefits earned by ambidextrous organizations, while neglecting another important aspect. More specifically, previous research focused

on aspects of quantitative growth that are less directly a measure of an innovation's economic value and incorporate all aspects of the business value chain activities that support an innovation, as well as competitive factors that affect the price of an innovation in the market. Measures such as sales increase (He & Wong, 2004), growth in sales and market share (Lubatkin, Simsek, Ling, & Veiga, 2006), profitability (Knott, 2002; Lubatkin, Simsek, Ling, & Veiga, 2006), or Tobin's q (Wang & Li, 2008) reflect the supporting activities of marketing, financing and distributing the innovation as well as the value of the innovation itself. On the other hand, a more direct measure of new value creation, or exploration degree of valuableness has been rarely emphasized, because of the difficulty in obtaining such direct measures. So, our second research question is whether organizational ambidexterity is beneficial for new value creation at the level of the pharmaceutical drug itself.

One of the main stumbling blocks to generating a more detailed understanding of the optimal balance between exploitation and exploration is the difficulty in obtaining fine-grained data that can objectively operationalize these constructs. The lack of studies on the source of more valuable exploratory innovation is also ascribed to the difficulty with precisely measuring the economic value of an innovation. While we recognize that exploration and exploitation can occur along any dimension of the business value chain, we restrict our interests to technological exploitation and exploration. Doing so allows us to leverage a detailed data on new pharmaceuticals development performance.

From this more fine-grained data set we intend to show as our conclusion that organizational ambidexterity is also beneficial in terms of exploratory innovation valuableness, and that the optimal balance between exploitation and exploration lies slightly toward exploitation. The next section reviews preceding research and provide theoretical underpinnings for our arguments. Our sample and research methods are discussed in a succeeding section. After reporting our findings, the paper concludes with some practical, as well as theoretical implications.

Theoretical Background

The Classic Trade-off between Exploitation and Exploration

As is stylized by Holland (1975), and then formalized by March (1991), the relationship between exploitation and exploration is defined as a trade-off. More precisely, exploitation is said to crowd out exploration. As organizations engage in more exploitative activities they would subsequently generate less exploratory activities (Abernathy, 1978; Argyris & Schon, 1978; Benner & Tushman, 2002; Henderson & Clark, 1990; Leonard-Barton, 1992; Levinthal & March, 1993; Prahalad & Bettis, 1986; Sull, 1999; Sorensen & Stuart, 2000). Although not explicitly stated in these studies, there is an implicit assumption that this is a one for one trade-off, with each unit of exploitative activity reducing exploratory activity by one unit.

The fundamental assumption for this argument is that exploitation requires distinctively different cognitive and behavioral patterns from exploration (Anderson & Tushman, 2001). Exploitation is usually related to improvements, increased efficiency and incremental adjustments, while exploration is closely linked with variety generation, distinctly new possibilities, distant search, and radical or revolutionary change (March, 1991). Therefore, although both of these activities are required for long-term organizational adaptation, organizations either over-exploit at the risk of losing major change opportunities (Levitt & March, 1988), or over-explore not fulfilling the efficiency increase potential of an innovation (Anderson & Tushman, 2001).

It is further asserted that the proportion of over-exploitative or over-exploratory activity in an organization is not equally valued. Initiatives associated with exploitation are preferentially selected by organizations, since they involve less risk, and promise more certain benefit in the shorter-term. Exploitation is more cognitively favored by managers, and from a behavioral point of view, fits better into the existing standard operating procedures. Consequently, organizations tend to engage in more exploitative activity than exploratory activity.

As is clearly shown in the above arguments, those who see a substitutional relationship between exploitation and exploration focus on the resource allocation trade-off between exploitation and exploration. The more resources an organization allocates to exploitative activities, the less the organization is motivated to allocate resources to exploratory ones, resulting in fewer exploratory achievements compared to exploitative ones. In other words, exploitation hinders an organization's ability to engage in exploration. This challenge confronting organizations and how organizations attempt to answer the challenge is critical to both their short-term and long-term survival. We next turn our attention to research that examines how organizations are confronting this challenge.

An Emerging Perspective: Organizational Ambidexterity

Although the trade-off relationship between exploitation and exploration is well established, recent research on organizational ambidexterity has uncovered that not all organizations are the victims of such a constrained either-or choice. The central thesis of this research on organizational ambidexterity contends that there are some common antecedents for exploitation and exploration irrespective of their ultimately mutually contradicting nature. These researchers start from the traditional assumption of the trade-off relationship between exploitation and exploration. However, they then try to identify some managerial interventions (Tushman, Anderson, & O'Reily, 1997), unique organizational contexts (Gibson & Birkinshaw, 2004), or top management team's behavioral integration (Lubatkin, Simsek, Ling, & Veiga, 2006) that resolves this trade-off relationship. As such, the burgeoning research on organizational ambidexterity potentially shows how organizations in general and global pharmaceutical companies in particular might both exploit the value of their libraries of existing chemical entities, as well as explore novel NCEs yet to be found.

One of the most familiar recommendations on how to reconcile these dichotomous resource allocation patterns is structural separation (Christensen & Bower, 1996; Cooper & Smith, 1992; Gilbert, 2005). Because exploitation and exploration cannot be simultaneously pursued in the same organization simultaneously, it is suggested that organizational units geared toward each of these activities should be separated. Based on this understanding, these scholars indicated that it is necessary to establish distinct organizational units with different orientations, i.e., one for exploitation (in most cases, an existing organizational unit), and another for exploration (again, in most cases a new organizational unit). This argument has received considerable empirical support (Afuah, 2001; Burgelman, 1983; McGrath, 2001; Puranam, Singh & Zollo, 2006; Rosenbloom & Christensen, 1994).

Another approach to address the trade-off relationship between exploitation and exploration is to temporally separate them. One of the most well known examples is the evolutionary pattern called punctuated equilibrium (Eldredge & Gould, 1972; Gersick, 1991; Tushman, Anderson & O'Reily, 1997; Tushman, Newman & Romanelli, 1986; Tushman & Romanelli, 1985). Seen from the punctuated equilibrium perspective, organizations are described to cyclically go through a period of convergence and a period of upheaval. The period of convergence is characterized by incremental improvements on knowledge, technology, or on organizational processes. The period of convergence is also associated with increasingly tighter coupling among decisions, actions, and organizational structures (Siggelkow, 2001). Whereas, the essence of this period is continuity, it is suddenly punctuated with episodic upheavals, or drastic reorientations (Tushman & Romanelli, 1985). The period of upheaval is full of drastic changes based on unknown fields of knowledge. Everything, including strategy, control systems, and the distribution of power is redefined. This redefinition undermines existing rules, standards, and structures. Since the magnitude of substantial changes is traumatic to organizational members, managers' heroic interventions are required to push through the disruptive changes required during the period of upheaval. In other words, without such heroic interventions, drastic reorientations and the resulting disruptive changes that are generated are doomed to fail due to organizational inertia. An organization is always under the pressure to repeat familiar procedures. Going beyond known fields requires disrupting an otherwise congealed web of mutually enhancing decisions, actions, and organizational structures that result in predictable behavioral results, enabling a firm to move into areas where the results are unpredictable.

While these arguments focus on how to divide exploitation and exploration either structurally or temporally, proponents for contextual ambidexterity argue organizations can be ambidextrous not by dividing exploitation and exploration, but by creating a unique organizational context supportive of both (Gibson & Birkinshaw, 2004). More specifically, under an organizational context characterized by a combination of stretch goals, discipline, managerial support and trust, organizational members belonging to a single organizational unit exploit and explore at the same time. The challenges of simultaneously pursuing exploitation and exploration cannot be fully attenuated even by this contextual ambidexterity. However, this unique organizational context empowers organizational members so they can strive for organizational ambidexterity more vigorously, by reducing concerns about the risks of failure in meeting stretch goals.

Although these arguments are theoretically sound and empirically verified, one critical question has not been adequately answered. We are beginning to understand how to pursue both

exploitation and exploration, but it is still not clear what the optimal balance between exploitation and exploration is or should be. Should organizations pursue equal amount of exploitation and exploration? If equal distribution were not the answer, what would be the optimal balance between them? The lack of understanding on the optimal degree of organizational ambidexterity is especially problematic for practitioners when they try to manage their organizations' resource allocation. Without knowing the optimal balance, managers have no clue whether they should increase (decrease) or decrease (increase) their resource allocation to exploitative (exploratory) initiatives.

Another shortcoming of the extant empirical work on organizational ambidexterity is that the performance benefits of innovations are measured in the more general terms of organizational growth, while direct measures of an innovation's economic value are not. Although such quantitative growth aspects, including sales increase (He & Wong, 2004), growth in sales and market share (Lubatkin, Simsek, Ling, & Veiga, 2006), profitability (Knott, 2002; Lubatkin, Simsek, Ling, & Veiga, 2006), Tobin's q (Wang & Li, 2008), or perceived well-being in terms of general firm performance (Gibson & Birkinshaw, 2004) are important parts of performance benefits, these reflect all the activities along the organization's value chain and have been used primarily because they are readily available. Measures of the direct economic value of an innovation should also be emphasized especially in the contexts of a firm's innovative behavior. For example, the aspect of new economic value creation is often more important in the context of product development. Originally, exploitation and exploration entail organizational learning and search (March, 1991). Therefore, it is surprising that existing research on organizational ambidexterity does not pay closer attention to the new economic value creation of an innovation. More generally, is organizational ambidexterity beneficial for generating new products with novel economic value? We intend to address this theoretically, as well as practically important question with a unique dataset on new pharmaceutical development in the Japanese market.

Methods

Sample

We address the question described above with data from new pharmaceutical development in the Japanese market. We focus on product development because organizational ambidexterity is defined as the ability to "simultaneously create both incremental and discontinuous innovation (Tushman & O'Reilly, 1997: 6)." Following this definition, prior studies operationalize organizational characteristics of ambidexterity by the extent to which firms simultaneously pursue both exploratory and exploitative product innovation (Benner & Tushman, 2003; He & Wong, 2004).

The Japanese market for new pharmaceuticals is quite appropriate for our purpose. All new ethical drugs need to be approved by the government (the Ministry of Health and Welfare), and an official reimbursement price is approved for each new pharmaceutical. This is quite different from the North American market where the Food and Drug Administration (FDA) approves all new pharmaceuticals, but there is no standard official price since each payer (i.e., insurance firms) decides its own reimbursement price. Although there are some other countries that use centralized pricing authorities to set the reimbursement price for pharmaceuticals, including Canada, France and Spain, Japan is by far the largest market among such countries, and hence most of global pharmaceutical firms actively participate in the Japanese market.

The second reason the Japanese new pharmaceutical market is appropriate for our study is that the official price for new ethical drugs is determined according to its degree of medical usefulness and effectiveness; which can be used as a proxy measure of the new pharmaceutical's degree of economic value. A pharmaceutical product is economically valuable to the extent that it effectively cures a patient's illness. Since the government is the biggest payer in Japan, new pharmaceutical's degree of economic value is primarily evaluated from the perspective of public welfare, including the health of the working population, containment of national healthcare expenses, and national prestige as an advanced nation. Pharmaceutical firms are rewarded by higher reimbursement prices to the extent that they fulfill their responsibilities to enhance the public welfare. Higher reimbursement price is also economically valuable for pharmaceutical firms, since it benefits them both directly (through higher revenue) and indirectly (through reputation as being more innovative).

The evaluation of medical valuableness is reliable and precise because the government delegates to independent specialists, including physicians, scientists, payers, and pharmaceutical firms the requirement to determine the improved

efficacy of the new pharmaceutical. This is a highly rigorous and comprehensive measurement process since these specialists make every possible effort to fairly and consistently evaluate each new pharmaceutical because the Japanese government is concerned about balancing two competing social welfare needs, i.e., containing pharmaceutical costs and promoting developments of effective pharmaceuticals. In other words, reimbursement for non-innovative pharmaceuticals should be tightly controlled, while truly innovative ones should be compensated for by a lucrative reimbursement price.

The third reason we selected new pharmaceutical development in the Japanese market, is that the independent specialists also determine which aspect of each new pharmaceutical is evaluated as new. More specifically, each newly developed pharmaceutical is categorized into 9 application classes, including NCE (new chemical entity), change in dosage, change in delivery, change (or addition of) indication, change in form, addition of form, mixture of existing NCE, modified mixture, and others. This classification is useful for our operationalization, since the NCE classification is traditionally thought to represent exploration in the context of new pharmaceutical development, while the other classifications are thought to represent exploitation (Bierly & Chakrabarti, 1996; Cardinal, 2001; Dunlap-Hinkler, Kotabe, & Mudambi, 2010). An NCE represents a totally new chemical entity that did not exist as an ethical pharmaceutical drug. So finding a NCE requires a search beyond known libraries of active ingredients, while a non-NCE reuses NCEs already approved for medical use. Consequently, the measure we are using is a more direct measure of the economic value of the innovation because it does not include the distortion of other value chain activities that exists in measures such as sales, sales growth and profits or profit growth.

We constructed a database on new pharmaceutical approvals from June 1999 to March 2009 (excerpts of database entries are shown in the appendix). During the 11 years, 259 new pharmaceuticals with new NCEs developed by 99 firms were approved for reimbursement, while 376 new pharmaceuticals reusing then-existing NCEs were approved. Our database includes additional information on these new pharmaceuticals, such as the therapeutic area of indication, drug type (internal, external, or injection), approved reimbursement price, firms who developed each pharmaceutical, and application class. As for data on firms, we also added information on whether each pharmaceutical was developed by a single firm or generated through some R&D alliances among multiple firms. We were also able to include in our database, cases where the pharmaceutical gained orphan drug status[1].

All this information was available from governmental public announcements on new approvals. The database on new pharmaceutical approval is paired with another database on each firm's pharmaceutical pipelines. Pipelines are pharmaceutical candidates under development. A professional medical magazine, called *New Current*, has been publishing exhaustive lists of pharmaceuticals under development since 1990. Leveraging their lists, we gathered data on pipelines at 1990, 1995, 2000, and 2005 for 98 firms listed on a new NCE pharmaceutical approvals list. Since new pharmaceutical development takes on average between 8-12 (Pisano & Rossi, 1994) or 7-11 (Powell, Koput, & Smith-Doerr, 1996) years, we expect our pipeline data covers most of those new pharmaceuticals listed on 1999-2009 approvals[2].

Variables and Analysis

In order to understand the optimal degree of organizational ambidexterity, we construct the measure of organizational ambidexterity and test its association with sample firms' exploratory innovation performance in terms of exploratory degree of valuableness. The unit of analysis is each new NCE pharmaceutical approved for reimbursement.

Dependent variable (exploratory degree of valuableness). Our dependent variable is each new NCE pharmaceutical's reimbursement price standardized for one-day usage. Since the official reimbursement price is set at the minimum units of packaging (i.e., per pill, or per vial), standardization for one-day usage is necessary for fair comparability[3].

This is the economic value of the innovation or its exploratory degree of valuableness. Since

1) Orphan drugs are those pharmaceuticals for very rare and serious diseases. Governments grant several preferential treatment including expedited approval and a higher reimbursement price, so that pharmaceutical firms would be compensated for smaller market opportunities.

2) Since pipeline identifiers often change (usually from serial numbers to unique names) during development, it is extremely difficult to make sure an exact match between pipeline data and approval data.

3) For example, the reimbursement price for Takeda's diabetes drug, Actos (pioglitazone hydrochloride), was set at 119.2 yen per pill, and it's allowed for 3 pills pre day. It gives us 357.6 (119.2*3) yen as Actos's reimbursement price standardized for one-day usage.

the Japanese economy had been under deflation during most of our observation period, it was not necessary to make any inflation adjustment on the reimbursement prices. The distribution of this variable is highly skewed, so we took the natural logarithm of new NCE pharmaceutical's reimbursement price standardized for one-day usage.

Independent variables. Our independent variable measures each firm's degree of organizational ambidexterity in terms of their development resource allocation to non-NCE as well as NCE pipelines. Our measure of organizational ambidexterity is defined as one divided by |x - a|+0.001, where x is the total non-NCE pharmaceutical pipeline counts of 1990, 1995, 2000, and 2005, divided by the total number of pipelines (non-NCE as well as NCE) over the same period. In our study, "a" denotes a threshold balance between exploration and exploitation, which divides over (under) and under (over) exploitation (exploration). Consequently, |x - a| indicates the degree of deviation from that threshold for each firm. We take the reciprocal of this value so that a higher measure indicates a higher degree of organizational ambidexterity. Since x equals a for some firms, we add 0.001 to the denominator. Then, we vary the value of a to see which sets of our independent variables with differing threshold values show a significant association with our dependent variable. The threshold value with a significant positive association with our dependent variable is concluded to be an optimal degree of organizational ambidexterity.

Control variables. We included several control variables in order to control the effects of alternative explanatory factors. More specifically, we controlled for R&D spending, as well as whether each firm is a biotech company or not (dummy variable). In addition, several dummy variables on each new pharmaceutical's characteristics are also included.

Preceding studies have found that the size of an organization affects its innovative performance (Camisón-Zornoza, Lapiedra-Alcamí, Segarra-Ciprés, & Boronat-Navarro, 2004). When we analyze product development performance at pharmaceutical firms, R&D spending would be the best measure for operationalizing size, because it decides the number and the quality of researchers firms can hire (Dunlap-Hinkler, Kotabe, & Mudambi, 2010). We collected data on R&D spending from Iyakuhin-kigyo Soran (A Directly for Pharmaceutical Firms) and Datastream at 1995, 2000, and 2005, and averaged them for each firm. Since pharmaceutical firms are relatively consistent and do not drastically change the level of R&D spending due to the fact that pharmaceutical development is a multi-year endeavor with cumulative effects of R&D investment, we believe our measure reasonably captures the substance of size variances among the sampled firms. As is customary, the variable is put in the model in natural logarithm (Greene, 2000; Long, 1997).

We also feel it necessary to control for whether a firm is a biotech company, because biotechnology is a competence-destroying innovation (Nelson, 1994; Powell, Koput, & Smith-Doerr, 1996), in that it is a new technological regimen compared to the traditional chemical based method of developing new pharmaceuticals . Consequently, risk preference characteristics are quite different between biotech firms and traditional pharmaceutical firms, which should affect the relationship between exploitation and exploration.

In addition to these control variables, several dummy variables on each pharmaceutical's characteristics are included. First of all, whether those NCE pharmaceuticals are developed as a result of R&D alliances or not is included. An alliance between pharmaceutical companies is expected to positively affect innovative performance, since allied firms are able to deploy more resources, as well as to draw on diversified sources of knowledge. Therefore, we include a dummy variable that shows whether those NCE pharmaceuticals are developed as a result of R&D alliances or not.

Secondly, the NCE pharmaceutical's therapeutic area is expected to affect reimbursement price. Specifically, those NCE pharmaceuticals with indications of cancer or infectious diseases generally are granted a higher reimbursement price, because they have been Japan's and the World's most fatal diseases respectively. Types of NCE pharmaceuticals are also an important consideration for setting reimbursement price. Generally speaking, injection NCE pharmaceuticals are expected to be more expensive, since they are administered only by physicians, and thus could contain stronger active ingredients[5]. Finally, those NCE pharmaceuticals with orphan drug status are also granted higher reimbursement prices so that pharmaceutical firms are compensated for the smaller market size. Overall, the availability of data reduces our sample down to 231.

Self-injection is not allowed in Japan, except for limited indications including diabetes.

Statistical Method

The data includes repeated observations for the same firm. In order to account for autocorrelation that may arise because each firm is measured repeatedly across multiple times, we employed the GEE (generalized estimating equations) regression method (Liang & Zeger, 1986).

Descriptive statistics and correlations for all the key variables are reported in table 1 for the case of a equals 0.58 (which we found to be the most significant results as we report below). Overall, the independent and control variables show considerable variance, and most correlations among the variables range from small to moderate. We also checked VIF (variance inflation factors) for all variables in all models and none of them exceeds 2, which indicates a very limited threat of multicollinearity.

Results

Table 2 and 3 report the results of our analysis on organizational ambidexterity and exploration degree of valuableness. Specifically, Table 2 reports the results for a between 0.1 and 0.9 with 0.1 increments, while Table 3 reports the results for a between 0.52 and 0.64 with 0.02 increments. QIC (quasi-information criterion) are reported at the bottom of the table, indicating how each model with smaller QICs improves upon the base model, which includes only control variables (Pan, 2001).

Model 1a and model 2a show the results with the control variables only. Model 1b through 1j and 2b through 2h add the independent variables. Here, we discuss the results from models focused on our main effects, i.e., model 1b through 1j for Table 2, and model 2b through 2h for Table 3 respectively.

We first examine the coefficients for the degree of organizational ambidexterity in model 1b through 1j reported in Table 2. The significant ($p < .05$) and positive coefficient is identified for the case of a equals 0.1 (model 1b). Although marginally, the significant ($p < .10$) and positive coefficient is also found for the case of a equals 0.6 (model 1g). For other values of a, we fail to find significant coefficients.

As for the control variables, most of them show significant coefficients in the expected direction, except for R&D spending and alliance. R&D spending does not show significant coefficients. As for the alliance variable, the results show a negative and significant ($p < .001$) coefficient, indicating alliances are used more for covering each other's weakness, rather than

Table 1 Descriptive Statistics and Correlations: a = 0.58 a

Variable	Mean	s.d.	1		2		3		4		5		6		7		8
1. Reimbursement price [a]	8,19	2,51															
2. R&D spending [a]	11,07	1,44	,09														
3. Biotech	0,04	0,20	,39	**	-,14	*											
4. Alliances	0,17	0,38	-,38	**	-,29	**	-,10										
5. Cancer indication	0,16	0,36	,22	**	,15	*	-,03		-,07								
6. Infectious disease indication	0,25	0,43	,17	**	,02		-,02		-,18	**	-,25	**					
7. Injection	0,36	0,48	,67	**	-,01		,24	**	-,25	**	,08		,03				
8. Orphan drug	0,11	0,31	,33	**	-,01		,13	*	-,12		,08		,09		,18	**	
9. Ambidexterity (a = 0.58)	4,85	7,20	,09		-,05		,01		-,08		-,03		,11		,06		-,05
"a natural logarithm * p < .05 ** p < .01"																	

Table 2 Results of GEE regression analysis for the effects of ambidextrous resource allocation on exploration degree of valuableness [a]

	Model 1a (Base model)			Model 1b (a = 0.1)			Model 1c (a = 0.2)			Model 1d (a = 0.3)			Model 1e (a = 0.4)		
R&D spending [b]	0,10		(,08)	0,10		(,09)	0,10		(,08)	0,10		(,08)	0,10		(,08)
Biotech	2,98	**	(,92)	1,81		(1,15)	2,98	**	(,92)	2,98	**	(,92)	3,02	**	(,93)
Alliances	-0,96	***	(,23)	-0,96	***	(,23)	-0,96	***	(,23)	-0,96	***	(,23)	-0,97	***	(,23)
Cancer indication	1,34	***	(,34)	1,37	***	(,33)	1,33	***	(,34)	1,34	***	(,33)	1,34	***	(,33)
Infectious disease indication	0,96	***	(,23)	0,96	***	(,22)	0,95	***	(,23)	0,96	***	(,23)	0,96	***	(,23)
Injection	2,76	***	(,23)	2,73	***	(,23)	2,76	***	(,23)	2,76	***	(,23)	2,76	***	(,23)
Orphan drug	1,26	**	(,42)	1,32	***	(,39)	1,26	**	(,42)	1,26	**	(,42)	1,27	**	(,41)
Ambidexterity				0,00	*	(,00)	0,00		(,00)	0,00		(,00)	0,00		(,00)
Constant	5,55	***	(,93)	5,54	***	(,94)	5,54	***	(,93)	5,55	***	(,92)	5,50	***	(,91)
QIC	155,152			539,939			555,444			555,769			555,201		

	Model 1f (a = 0.5)			Model 1g (a = 0.6)			Model 1h (a = 0.7)			Model 1i (a = 0.8)			Model 1j (a = 0.9)		
R&D spending [b]	0,11		(,08)	0,11		(,08)	0,11		(,08)	0,11		(,08)	0,11		(,08)
Biotech	2,88	**	(1,00)	2,95	**	(,96)	2,89	**	(,97)	2,92	**	(,98)	2,95	**	(,98)
Alliances	-0,94	***	(,23)	-0,91	***	(,23)	-0,92	***	(,24)	-0,91	***	(,24)	-0,91	***	(,24)
Cancer indication	1,35	***	(,34)	1,34	***	(,34)	1,35	***	(,34)	1,35	***	(,34)	1,35	***	(,34)
Infectious disease indication	0,97	***	(,23)	0,94	***	(,23)	0,98	***	(,23)	0,98	***	(,23)	0,98	***	(,23)
Injection	2,77	***	(,23)	2,77	***	(,23)	2,78	***	(,23)	2,78	***	(,23)	2,78	***	(,23)
Orphan drug	1,28	**	(,42)	1,31	**	(,41)	1,29	**	(,41)	1,30	**	(,41)	1,30	**	(,41)
Ambidexterity	0,00		(,00)	0,05	†	(,03)	0,04		(,04)	0,18		(,15)	0,32		(,28)
Constant	5,46	***	(,93)	5,22	***	(,93)	5,30	***	(,93)	5,04	***	(,98)	4,89	***	(1,06
QIC	554,271			553,013			554,710			554,699			555,012		

"a n = 231 observations. Numbers in parentheses are standard errors. Tow-tailed tests for all effects.b natural logarithm

† p < .1

* p < .05

** p < .01

*** p < .001

Table 3 Results of GEE regression analysis for the effects of ambidextrous resource allocation on exploration degree of valuableness [a]

	Model 2a (Base model)			Model 2b (a = 0.52)			Model 2c (a = 0.54)			Model 2d (a = 0.56)		
R&D spending [b]	0,10		(,08)	0,11		(,09)	0,11		(,09)	0,11		(,08)
Biotech	2,98	**	(,92)	2,96	**	(,95)	2,98	**	(,92)	2,98	**	(,94)
Alliances	-0,96	***	(,23)	-0,94	***	(,24)	-0,95	***	(,24)	-0,93	***	(,23)
Cancer indication	1,34	***	(,34)	1,33	***	(,34)	1,34	***	(,34)	1,33	***	(,34)
Infectious disease indication	0,96	***	(,23)	0,96	***	(,23)	0,95	***	(,23)	0,93	***	(,23)
Injection	2,76	***	(,23)	2,77	***	(,23)	2,77	***	(,23)	2,77	***	(,23)
Orphan drug	1,26	**	(,42)	1,28	**	(,42)	1,27	**	(,42)	1,29	**	(,42)
Ambidexterity				0,01		(,01)	0,00		(,00)	0,02	*	(,01)
Constant	5,55	***	(,93)	5,44	***	(,96)	5,47	***	(,95)	5,53	***	(,93)
QIC	155,152			556,329			555,078			553,399		

	Model 2e (a = 0.58)			Model 2f (a = 0.60)			Model 2g (a = 0.62)			Model 2h (a = 0.64)		
R&D spending [b]	0,11		(,08)	0,11		(,08)	0,11		(,08)	0,11		(,08)
Biotech	2,99	**	(,94)	2,95	**	(,96)	2,91	**	(,98)	2,89	**	(,97)
Alliances	-0,94	***	(,23)	-0,91	***	(,23)	-0,90	***	(,24)	-0,91	***	(,24)
Cancer indication	1,33	***	(,34)	1,34	***	(,34)	1,34	***	(,34)	1,35	***	(,34)
Infectious disease indication	0,93	***	(,23)	0,94	***	(,23)	0,96	***	(,23)	0,98	***	(,23)
Injection	2,75	***	(,23)	2,77	***	(,23)	2,78	***	(,23)	2,78	***	(,23)
Orphan drug	1,30	**	(,41)	1,31	**	(,41)	1,31	**	(,41)	1,30	**	(,41)
Ambidexterity	0,02	***	(,01)	0,05	†	(,03)	0,05		(,04)	0,03		(,03)
Constant	5,39	***	(,92)	5,22	***	(,93)	5,18	***	(,94)	5,28	***	(,93)
QIC	552,319			553,013			553,579			554,409		

"a n = 231 observations. Numbers in parentheses are standard errors. Tow-tailed tests for all effects.b natural logarithm
† p < .1
* p < .05
** p < .01
*** p < .001

complementing each other's strength. Other control variables including biotech ($p < .001$), cancer indication ($p < .001$), and infectious disease indication ($p < .001$), injection ($p < .001$), and orphan drug ($p < .01$) show significant and positive coefficients as expected.

Model 2b through 2h in Table 3 report our tests with a varying with smaller increments around the value we found statistically significant. More specifically, we vary a with 0.02 increments between 0.52 and 0.64 to identify the optimal degree of organizational ambidexterity in more detail. The examination of coefficients for organizational ambidexterity variables show that significant and positive associations are identified when a equals 0.56 ($p < .05$, model 2d), 0.58 ($p < .001$, model 2e), as well as 0.60 ($p < .10$, model 2f). For other values of a, we fail to find significant coefficients. We also ran a similar analysis varying a between 0.02 and 0.14, with 0.02 increments, but found no significant and positive coefficients except for the case of a equals 0.1 as reported above (results are available from authors upon request).

Discussion

We examined in this paper the important research question, what is the optimal degree of organizational ambidexterity. Our conclusion from our analysis of new pharmaceutical products development is that the optimal degree of organizational ambidexterity is not necessarily the even allocation of resources between exploitation and exploration. The finding also shows organizational ambidexterity is beneficial, not only in terms of organizational growth as measured by sales and other indirect measures, but also more directly in terms of new value creation represented in new product development.

We found that the optimal allocation in terms of exploration degree of valuableness is achieved when either 10 percent or 58-60 percent of pipelines are exploitative or when they are either 90 percent or approximately 40 percent exploratory. Interestingly enough, we find that there are two distinct approaches to realize higher exploration degree of valuableness through organizational ambidexterity. The former approach may be consistent with our conventional image of the high technology organization and in particular high technology start ups. Most resources are dedicated to exploratory search, so that radically novel innovation will be generated. It is interesting to note that some exploitative resource allocation is worthwhile even in this type of organizational contexts. On the other hand, the latter approach is more aligned with our notion of an ambidextrous organization, often an incumbent firm in an industry. The balance is subtle in that it indicates the importance of the simultaneous pursuit of both exploitation and exploration, while emphasizing that roughly 1.5 times more allocation to exploitative pipelines than to exploratory ones is optimal. Whereas the former approach of allocating 90 percent to exploration is found to be beneficial in terms of exploratory degree of valuableness, we doubt it provides sufficient benefits in terms of efficient short-term product developments with exploitative nature and consequently could effect an organizations short-term survival. This is often the case with high technology start ups that must rely on regular infusions of capital from venture capitalists in order to survive until their exploratory breakthrough product is developed and marketed. Therefore, we focus on the latter approach and discuss some implications for practitioners involved in pharmaceutical products development in incumbent pharmaceutical companies.

First of all, managers must pay close attention to how many resources are allocated to non-NCE pipelines when they try to develop more valuable NCE pharmaceutical products. This is because developing more valuable NCE pharmaceutical products benefits from maintaining substantial amount of non-NCE pipelines. This might sound counter-intuitive, but there are some examples that show this is in fact the case. For example, the useful experience of later phase developments is more frequently learned by being involved in non-NCE pharmaceutical products development, since NCE pipelines are more likely to fail in early stages than are non-NCE pipelines. Thus the late stage experience gained through having non-NCEs can be applied to the NCEs that make it into the latter stages of development. In addition, non-NCE products are more likely to generate financial resources with a shorter lead-time, and be more sustaining over time providing a more munificent organizational milieu for NCE product development. Off-course, excessive resource allocation to exploitative pipelines will erode a firms' capability to generate blockbuster products. Our finding on the critical threshold value of 0.56-0.60 should help managers to discern whether they should increase or decrease exploitative resource allocation in order to remain on-course.

By providing this guideline we are making explicit the rough rules of thump that managers may have been tacitly making. However, given the limits of our data we realize that these numbers should be used with care. Since the

product development cycle of the pharmaceutical industry is long, ranging from 7-12 years, and takes into account many steps, such as discovery, preclinical and clinical testing and such, we are not implying that the optimal ambidexterity level should be maintained at 1.5 throughout the entire process of development of a pharmaceutical drug. Our results indicate that firms that have a resultant mix of approximately 1.5 times exploitative activities will have an optimal mix of ambidexterity, which in turn will provide greater resources for conducting their exploratory product development activities.

Secondly, managers need to address the trade-off relationship between exploration frequency and exploration valuableness. One of the most obvious ways to increase the probability that pharmaceutical firms could successfully develop more NCE pharmaceutical products is to increase the resources dedicated to the development of NCE pipelines. However, increasing NCE pipelines inevitably reduces non-NCE pipelines unless the overall development budget is increased. Therefore, given our finding that a predominantly exploitative pipeline portfolio is positively associated with more valuable NCE products, there is a trade-off relationship between exploration frequency and exploration valuableness. By pursuing organizational ambidexterity, managers are able to circumvent the traditional trade-off relationship between exploitation and exploration. However, even ambidextrous organizations require sound managerial decision-making on how to balance exploration frequency and exploration valuableness. Managers will need to consider the idiosyncratic elements that are unique to each of their individual firms, in order to make the adjustment necessary to enhance their own successful conversion rate between those chemical entities beginning a pipeline and those resulting in a new pharmaceutical drug.

In addition to these implications for practitioners, our finding provides some theoretical implications for future academic research.

First of all, we show organizational ambidexterity is beneficial for organizational performance in terms of new value creation at the level of the pharmaceutical drug. Prior works on organizational ambidexterity predominantly focused on less direct growth-oriented measures like sales growth or profitability, mainly due to the difficulty in operationalizing the degree of valuableness of innovation in terms of each product developed. By using a unique measure of the more substantive aspects of the degree of valuableness, we are able to observe the beneficial effects of organizational ambidexterity in product development. Product innovation activities are only one sub-system, albeit an important sub-system in the firm's set of sub-systems that comprise the overall value chain. Thus, we show the value of innovation activities at the level of the product, we do not address how well the firms do in converting the higher value of each innovation into higher firm value. Consequently, we leave open the question of how well the ambidextrous company does at generating value at the overall level of the firm. This would be one promising area for future research.

Secondly, our study shows there is another promising research direction to uncover the determinants of optimal degree of organizational ambidexterity. Our finding clarifies that there is a distinction between beneficial and non-beneficial ambidexterity, depending on the mix of exploitation and exploration. The finding is interesting in itself, but we were not able to provide an explanation of how this optimal mix is determined. We speculate that the degree of environmental stability is one of the key determinants, but an empirical verification is beyond the scope of the current paper. One future approach we could follow is to conduct a cross-industry analysis. Considering the fact that the pharmaceutical industry is one of the most quickly changing industries due to its technology intensive nature, we expect that the optimal mix of exploitation and exploration should be more skewed toward exploitation in the case of most other industries classified as middle to low technology industries.

Thirdly, another interesting research direction indicated by our results is to consider why a balance slightly skewed toward exploitation is beneficial for new value creation. In other words, it is necessary to understand how exploitation could increase subsequent exploration's degree of valuableness. One plausible explanation is the knowledge accumulated through incremental refinements associated with non-NCE pharmaceuticals development help in the absorption of the new knowledge required for NCE development (Suzuki & Methé, 2010). Alternatively, it also might be possible to emphasize the underlying organizational dynamism, designed in the exploitative innovation process, i.e., such disciplines as formalization or milestone management that an organization exercises when they allocate very limited resources to exploratory initiatives. Specifically, the use of rigorous milestone or deadline management is reported to discipline the

otherwise haphazard process of exploration (Brown & Eisenhardt, 1997; Gersick & Hackman, 1990). Further, the distinct definition of roles and responsibilities also makes rather chaotic intra-organizational interactions accompanying exploration more manageable (Sine, Mitsuhashi & Kirsch, 2006). Even bureaucracy, so often infamously portrayed as antagonist towards innovative spirits, has been shown to be instrumental in facilitating employees in the learning process, thus facilitating exploration under certain conditions (Adler & Borys, 1996).

Irrespective of all these contributions, our paper is not free from limitations, which open up further opportunities for future research. First of all, our results might have been strongly affected by the pharmaceutical industry's knowledge-intensive nature. If other more capital-intensive and less knowledge-intensive or moderate to low technology intensive industries are studied, the association between exploitative resource allocation patterns and subsequent exploratory innovation performance could be weaker. Thus, a cross industrial study would be an interesting avenue for future research. In addition, our research focuses on only one aspect of exploratory innovation. Although we feel it important to clarify hitherto neglected performance benefits in terms of exploration degree of valuableness, whether organizations should pursue ambidexterity or not depends on overall performance benefits in terms of both value creation and growth. Future research should take these two distinct aspects into consideration when performance benefits earned from organizational ambidexterity are examined. This could be accomplished by mixing the traditional measures of sales and profit with more direct measures of an innovations economic value. Thirdly, our independent variable on the degree of organizational ambidexterity measures a firm's resource allocation only indirectly. Ideally speaking, the amount of resources allocated to non-NCE and NCE products development could be measured in terms of monetary amounts. Such an analysis with more precise data tying the financial resources directly to NCE and non-NCE development, would most likely show a more substantial skew toward exploitative resource allocation, since non-NCE developments are more likely to survive until the later and more costly development stages. Finally, our research has examined how firms conduct product development activities in markets in a developed economy characterized with centralized pricing authorities. It would be valuable to conduct this type of study in markets where the pricing authority is less centralized. And in an economy which is still in the process of developing its institutional infrastructure, such as intellectual property rights (IPR).

Research on organizational ambidexterity generates the opportunity to reinterpret the long-established dichotomous relationship between exploitation and exploration. Yet, its potential is barely appreciated by practitioners due to the obvious lack of clear guidelines for applying the findings' implications to actual managerial practices. It also is unfortunate that the lack of appropriate measures on the consequential benefits of ambidexterity hinders its appreciation by managers involved in new product developments. We hope our study will stimulate practical, as well as scholarly discussions on how to leverage the findings on organizational ambidexterity for the creation of novel value.

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Research Paper

The challenges and opportunities of the European Union lead market initiative: case bio-based products

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The role of innovations as an engine for European competitiveness is largely accepted as a part of the EU Lisbon strategy, and the Lead Market Initiative (LMI) has been seen as an innovative platform for advancing the knowledge-based bio-economy in Europe. Our research questions are; first, what are the main challenges and opportunities of the LMI on bio-based products in comparison to other EU initiatives such as JTIs and CIP? Second, does the LMI address those challenges adequately, and what areas of improvement can be identified? Methodologically, we use a qualitative case study approach with data from both documentary sources and in-depth elite interviews. Based on our results, the strong demand-side characteristics of LMI, such as public procurement, standardization and legislation, can accelerate the time-to-market in case of the bio-based products and services. However, the speed of diffusion is dependent on overcoming the problems of the critical-mass market creation and fragmented supply-side of bio-based industry. Ensuring coherence and coordination of activities between policy-makers in the Member states, EU Commission services, businesses and other stakeholders is also crucial to the success of LMI for bio-based products.

1 Introduction

Economic globalization has changed the world's economic order in a remarkably short time and has brought new challenges and opportunities. Europe will not be able to compete in this new environment unless it becomes more innovative and responds more effectively to consumer needs and preferences (European Commission, 2010). The EU Lisbon strategy has addressed these challenges, aiming to stimulate growth and create more and better jobs while making the economy greener and more innovative. Innovative use of renewable raw materials could be the key to utilizing the important potential of biomass in Europe. According to Van Dam et al. (2005), innovations and new product development are the essential parts of the commercial attractiveness of bio-based products, and industries should be encouraged to market more ecologically improved products based upon sustainable production.

A new impetus for demand-side innovation policies has emerged during the 2000s, as a response to insufficiency of traditional supply-side innovation policies to meet the challenges posed in promoting competitiveness of European Union, with the aim of focusing on the creation of innovation-friendly markets, strengthening R & D resources, increasing structural mobility, and fostering a culture, which celebrates innovation (Edler and Georghiou, 2007 p. 951). Demand-side innovation policy, and in particular the role of public procurement, has been at the centre of recent discussions on innovation policy (Aschhoff and Sofka, 2009).

The Lead Market Initiative (LMI) is the European policy for six important sectors that are supported by actions to lower barriers to bringing new products or services to the market in bio-based products, e-health, protective

textiles, recycling, renewable energy and sustainable construction (European Commission, 2009a). The European Commission, Member States and industry work together to carry out the action plans for these lead markets. According to the European Commission (2007), bio-based products are non-food products derived from biomass (i.e., plants, algae, crops, trees, marine organisms and biological waste from households, animals and food production). Bio-based products may range from high value-added fine chemicals such as pharmaceuticals, cosmetics, food additives, etc., to high volume materials such as general bio polymers or chemical feedstock (i.e., building blocks). The definition pointedly excludes traditional bio-based products, such as pulp and paper, wood products and biomass as an energy source.

According to Beise (2004), the lead markets refer to the countries that first adopt a dominant global innovation design; they lead the international diffusion of an innovation and set the global standard. The aim of the LMI used by the European Commission is "to identify the first set of markets with the potential to become ´lead markets´ calling for urgent and coordinated action through ambitious action plans for these markets, in order to rapidly bring visible advantage for Europe's economy and consumers" (European Commission Communication, 2007). The six target sectors including bio-based products were selected based on their strategic importance to the innovative and competitive Europe, but also because of the relatively strong role of public sector demand in these products and services.

However, there are also several other programmes and initiatives in the European Union for the bio-based products concurrently directed towards the bio-based sector in addition to the Lead Market Initiative (LMI); the 7th Framework Programme (FP7) and Joint Technology Initiatives (JTIs), the Competitiveness and Innovation Programme (CIP), the establishment of European Institute of Innovation Technology (EIT), and several European platforms such as the Sustainable Chemistry Platform (SusChem) and the Forest Sector Technology Platform (FTP).

The research questions of this paper are; first, what are the main challenges and opportunities of the LMI on bio-based products in comparison to other EU initiatives such as JTIs and CIP? Second, does the LMI address those challenges adequately, and what areas of improvement can be identified? We will also gain better understanding of the interplay between various European Commission driven innovation policy instruments towards the creation of the knowledge based bio-economy in EU, especially of the challenges in integrating public sector innovation into other policy fields.

2 Theoretical Background

Theoretical concepts connected to analysis of the Lead Market Initiative can be found in the literature on innovation management, especially related to innovation systems (Edquist and Hommen, 1999). Functions of innovation systems have previously been studied in Hekkert and Negro (2008), Malerba (2002) and Oltra and Maïder (2008), which focus on sectoral systems of innovation. In Kubeczko et al. (2006), the main question was the extent to which sectoral and other innovation systems support innovation performance in the European forestry sector. Aschhoff and Sofka (2009) have classified four main types of public innovation policy tools to consist of regulations, R & D subsidies, scientific and technological infrastructure and the use of public procurement. Finally, Bélis-Bergouignan and Levy (2010) have emphasized the need to integrate a stronger consideration of natural resources into the analysis of innovation systems.

Edquist (2008) separates four key activities in systems of innovation; 1) knowledge inputs to the innovation process (e.g., R&D, competence building through individual and organizational learning), 2) the demand-side activities, 3) providing constituents for systems of innovation (enhancing entrepreneurship and intrapreneurship to diversify existing firms, and creating new research organizations and policy agencies) and 4) support services for innovating firms. From the systems of innovation perspective, innovation policy is partly a question of supporting interactions in this system that identify existing technical and economic opportunities or create new ones. It can be also said that the selected initiatives function as innovation platforms, a forum bringing the stakeholders and networks required together. According to Malinen and Haahtela (2007), these forums take care of shared strategic processes and leadership of the network which finally leads to decision-making and possible investment related to the strategy.

The rationale for the more demand-side oriented innovation policy is associated with a range of market and system failures affecting the translation of needs into functioning markets for innovative products and services, but policy prescriptions emerging from "systems"

approaches to innovations tend to focus predominantly on the supply side of economic life (Edler and Georghiou, 2007). In a recent article Uyarra and Flanagan (2010) also point out that "there is an increasing consensus in innovation policy discussions that the demand side of innovation has been neglected". According to Ahvenharju et al. (2010) the development of the demand-side innovation policy is a relatively new field, and there is no sustainable theoretical background to develop these innovation policies. While it is widely recognized that by using public policies it is possible to affect demand in many fields, it is still unclear what principles one should use to choose the innovations and solutions or markets which should be advanced, for example, with standards and, at the same time, which are the effective public instruments. For example, public procurement in the EU is guided by national policy frameworks coupled with an overarching EU policy framework that is designed to open up the EU's public procurement market to competition, outlawing "buy national" policies and promoting the free movement of goods and services (Brammer and Walker, 2011).

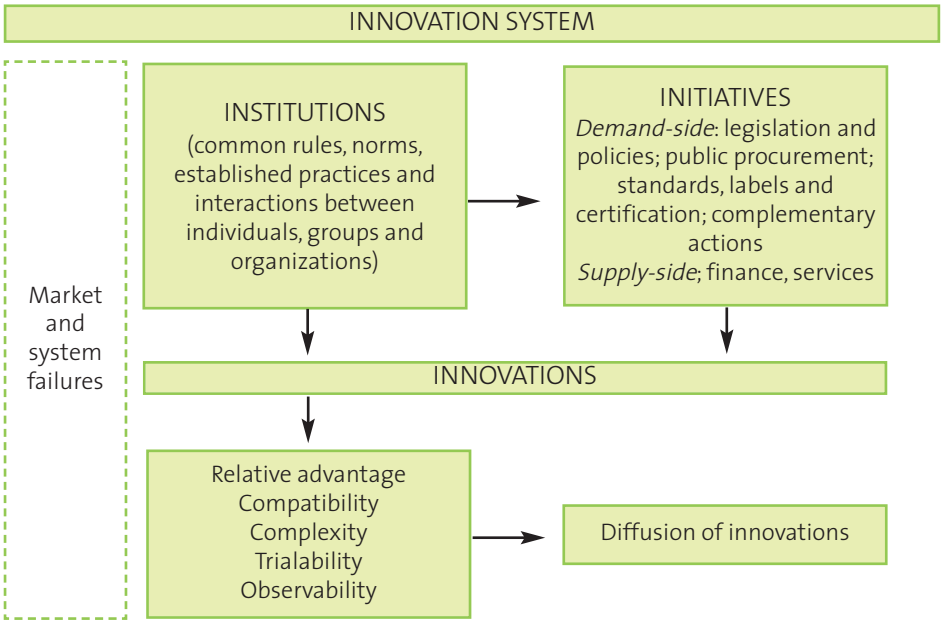
Beise and Cleff (2004, p. 455) have defined "lead markets" to be "regional markets with specific attributes that increase the probability that a locally preferred innovation design becomes internationally successful as well", as an extension of the concept "lead users" (von Hippel, 1986). As the relevant lead users we consider here the public sector, because of its public procurement practices, and private companies, but the question how these two groups differ from each other goes beyond the scope of our empirical analysis. According to Georghious and Edler (2007, p. 955) characteristics of a lead market include existence of customers willing to pay a premium for the particular characteristics of the innovation, general favorable conditions to innovations (such as an efficient and responsive regulatory structure and security to intellectual property), compatible infrastructure, sufficient market scale, and sufficiently generic products requirements to allow for expansion/export into wider markets.

The innovation diffusion approach (Rogers, 2003) also proves us measures to understand the mechanism behind successful policy initiatives better. According to Rogers (p.22), "diffusion is the process by which an innovation is communicated though particular channels over time among members of a social system", and the idea has been used in the several related studies (e.g., Beise and Rennings, 2006, Peres et al., 2010). According to Rogers (2003), time is involved in diffusion in (1) the innovation-diffusion process, (2) innovativeness, and (3) the rate of adoption of innovation. The innovation-decision process is that process through which an individual (or another decision-making unit) passes from the first knowledge of an innovation to forming an attitude toward the innovation, a decision to adopt or reject, to implementation of the new idea, and confirmation of this decision. Innovativeness is the degree to which an individual or other unit of adoption is relatively earlier in adoption of new ideas than other members of a social system.

Rogers (2003) formed five attributes facilitating diffusion of innovations as relative advantage, compatibility, complexity, trialability and observability. Rogers suggests that relative advantage, simplicity and an innovation's compatibility with a potential adopter's or organization's norms and procedures, account in particular for considerable variance in explaining adoption decisions. According to Dearing (2009), the other two attribute categories he distinguishes, observability and trialability, are not as consistently important across innovation types for producing adoption, though it is reasonable to assume that for high risk, expensive, and obtrusive innovations, trialability should be especially important, while for complex innovations with many process steps and those innovations that embed high degrees of ambiguity or tacit knowledge in their operation, the visibility of the innovation in the process and observability of outcomes should be especially important.

Based on literature review, we have formulated our theoretical framework as shown in Figure 1 to consist of the key role of institutions and initiatives within the innovation system, through which innovations for bio-based products are being created and diffused in Europe. Similar to most past research, we focus on predicting the rate of adoption based on the innovation attributes (Rogers, 2003). In the background, the theoretical framework also suggests that innovation system includes institutions and initiatives with inherent vulnerability to market and system failures. It should be noted that the system described in Figure 1 is meant for mainly serving as a guiding tool for conducting the interviews, and not meant to be understood to comprise any formal theoretical framework to be tested.

Figure 1 Theoretical framework (modified from Edler & Georghiou 2007, Edquist 2008, Oltra &Maïder 2008 and Rogers 2003).



3 Data and methods

Exploratory study of a phenomenon in a new context justifies the qualitative approach chosen for this study (Silverman, 2000). The methodology we used is a qualitative case study approach with data from both documentary sources and in-depth key stakeholder interviews. In qualitative studies, since it is desirable to use data and method triangulation to decrease the possibility of systematic delusion, the data of this study has been collected from various sources by interviewing multiple high-level experts. Data analysis has been conducted by using several theories to complete the triangulation.

Secondary data consists of previous research, literature and reports and working papers of the European Commission (including analysis of e.g. the LMI Mid-term Evaluation Report, 2009b). Since the data should be as rich as possible in terms of the research problem, the Commission members and the R&D&I and bio-based sector stakeholders, as the implementers of the European innovation policy actions, were among the core elite group to be interviewed (5 personal high-level interviews). Since all research themes were well covered by the interviews and convergence emerged between the respondents, even this small number of interviews was likely to be sufficient.

The internal validity of this study was ensured by drawing results logically from the data in combination with theory. Primary data is presented by summarizing the key notes on the responses and constructing an illustrative comparative table of the various initiatives. Internal validity was also ensured by linking the results to the existing literature (Eisenhardt, 1989).

Rich presentation of the initiatives improves the external validity of this study, which was particularly important, as the core research subject was one of the initiatives. The theoretical framework was formulated and operationalized based on the secondary data, which consists of previous research, literature and reports and working papers of the European Commission (e.g., analysis of the LMI mid-term evaluation report, 2009b).

Operationalization of the theoretical framework served as a guide formulating the background questions for the themed interviews and later when analysing the results gained from the data. Specific formulation of the research subject at the outset enabled the formulation of research questions and analysis of the primary and secondary data. The background questions were formulated according to the operationalization of the framework and the themes that arose during the research process were flexible enough to

give space for the discussions that arose during the interviews, so that they could be considered as relevant data. In the study, careful documentation was also used to ensure the reliability of the results. The questions were thoroughly explained during the interviews, in the case of unclear interpretation of concepts.

4 Results

4.1 Evolution and characteristics of the LMI for bio-based products

The idea of the Lead Market Initiative started in 2006, when Aho et al. (2006) introduced the concept of EU lead markets. The report recommended the development of innovation-friendly markets in a more targeted way by creating conditions to facilitate the transformation of technological and non-technological innovation into commercial products and services. The LMI was launched in 2007, and runs to 2012, but unfortunately no budgetary figures were given out at the time when this research was conducted. A plan of action for the next 3-5 years for each lead market was formulated, and the work started at the beginning of 2008. The governance structure and the progress of the initiative have been described in the mid-term progress report on the Lead Market Initiative (European Commission, 2009b) and the final evaluation of the initiative will be implemented in 2011. There is presently some evidence of new innovation policy developments in 12 out of 16 Member States partly as a result of and largely coinciding in a timely way with the LMI, and Finland, the UK and the Netherlands are now putting demand-side innovation policy at the centre of national innovation strategies.

Interestingly, the bio-refineries are included in the LMI on bio-based products, but other bio-energy products belong to the LMI on renewable energy. The LMI excludes traditional paper and wood products, but innovative bio-based products made from wood and lingo-cellulose are included in bio-based products. A representative of forest-based industry criticizes the exclusion of traditional wood-based products: *"it was a pity that they excluded these traditional wood-based products from the definition of the LMI on bio-based products. The areas should have been wider in the first place. It is good that there are those pharmaceuticals and vaccines but the traditional products could have been there also..."*

In bio-based products, there is already a growing demand for the new products provided that they are relatively competitive. According to the mid-term progress report (2009) *"as bio-based products are not one uniform product group, but a range of products with different characteristics and uses, the Lead Market Initiative helps to ensure the coherence of measures aiming to address demand-side problems with rules and regulations that govern the manufacturing process from raw material to final product."*

Legislation and policy activities of the LMI on bio-based products include the establishment of an advisory group, which includes representatives from Member countries and industries. According to the mid-term progress report of Lead Market Initiative for Europe (2009b), encouragement of Green Public Procurement (GPP) for bio-based products has been completed for public procurement actions. The GPP Communication proposes the way in which guidelines now include criteria that allow bio-based products to be given preference in tender specifications. Public procurement plays a major role by creating niche markets for environmental technologies, and by allowing feedback between experimental users and the emerging technology producers. A staff member of the Commission explains the challenges within the Commission, and the added value that the LMI has brought to the situation: *"the main challenge of these demand-side instruments is the cooperation between people with different backgrounds, for example, the people in public procurement."*

For the LMI on bio-based products, standardization and labelling, certification of product performance standards can help signal the environmental performance of products and processes. The Commission has identified a lack of suitable European standards for bio-based products, in particular for determining bio-based product content as well as other functional product capabilities, evaluation of environmental impacts, and a number of other purposes. One informant perceived positive progress: *"Before the LMI, public suppliers didn't have contacts with researchers, and the work of standardization developers was not linked to the work of innovation politicians."*

As supplementary actions, the Commission has already completed the mapping of bio-refineries, which can also be used as a platform to promote various new bio-based chemicals and materials. The European Commission sees partial progress on the LMI on bio-based products as also deriving from its decision to

Table 1 Key characteristics between LMI, CIP and JTIs (list of attributes by Rogers, 2003)

Innovation attributes	LMI - Lead Market Initiative on bio-based products	CIP - Competitive-ness and Innovation Programme	JTI - Joint Technology Initiatives
Relative advantage	Strong emphasis on the use of demand-side instruments	Wide scope (three specific programmes: EIP, ICT-PSP, IEE*)	Strong technology orientation
Compatibility	On a positive side, LMI instruments will remain in the innovation policy over the longer term On a negative side, costly to implement in full scale	Funds the networks, uses also demand side instruments	Focuses mostly on traditional supply side instruments
Complexity	Coordination of the EC is being criticized	Different EC departments deal with different CIP actions or programmes (shows in bureaucratic discussions in the Commission)	Success rate of the initiatives differs. EC strongly involved in funding
Trialability	Based on interviews, definition of bio-based products still unclear (except for the bio-based sector representative)	Not applicable	Not applicable
Observability	The LMI will merge under the Innovation Partnerships	Observability The LMI will merge under the Innovation Partnerships Research and innovation funding of CIP will be merged Not applicable	Not applicable

* The Entrepreneurship and Innovation Programme, The Information Communication Technologies Policy Support Programme, The Intelligent Energy Europe Programme.

start a major research initiative on the sustainable use of biomass in March 2010 under FP7. Long-term implementation is also planned for actions which propose and implement the elaboration of normative documents for Life Cycle Assessment (LCA) methodology related to bio-based products, e.g., European guidance documents, technical reports and standards. As an example, the Joint Research Centre (JRC) is developing a methodology for information about sustainability of biomass production, which is also part of the long-term implementation of the LMI on bio-based products.

Table 1 briefly compares the LMI and two other key technology instruments of EU, namely CIP and JTIs. We identified demand side orientation in the LMI as its relative advantage, which should be more efficient in supporting market creation and speeding up the time to market in case of new bio-based products and services, as compared to other initiatives with stronger focus on traditional supply side instruments. On the other hand, from compatibility point of view, the LMI involves costly measures, and there was impression that European Commission has had difficulties in terms of coordination of the initiative. The use of information guidance on the program content has also failed, since the definition of what products qualify as relevant bio-based products included in the LMI was still unclear even for some of our high level experts.

The Competition and Innovativeness Programme (CIP) runs from 2007 to 2013 with

an overall budget of €3621 mill., the main target being to enhance competitiveness of small and medium-sized enterprises in Europe. The program supports innovation (including eco-innovation), provides improved access to finance and delivers business support services in the regions. Demand side instruments strongly present in the LMI have been included in the CIP, but the challenge has been in the compatibility, in the adoption of these tools in practice.

The CIP has a wide scope as it is further divided into three operational programs, each of which has its specific objectives. One of the objectives of its' Entrepreneurship and Innovation Programme (EIP), which is related to the LMI, is to support policy-making that encourages innovation. A member of the Commission staff criticizes the current discussion of the CIP within the Commission: *"when it comes to the CIP, the actual conversations concentrate on the bureaucratic issues. Is there going to be another CIP after 2013 or should these research and innovation issues be put together. This discussion is nothing to do with content…The instruments will be used together anyways, as can be seen from the new innovation strategy, which was published today. It is not relevant to consider whether they should be under one or two programs. This is the current discussion in the Commission and it is the old story about internal power-sharing. Who is responsible for what…This is often the problem, and indeed, it doesn't help understanding the real issues, especially if one doesn't know the power structure of the Commission…When it comes to content everybody usually agrees."*

As mentioned in the Introduction, the 7th Framework Programme (FP7) consists of many areas in which the bio-based sector has ample possibilities to participate in the calls for proposals and apply for funding. Since the FP7 as an entity is far too large for this case study, the Joint Technology Initiatives (JTIs) – part of the Framework Programme – has been chosen for comparison with the LMI in this study. For the bio-based sector, JTIs such as the Nanoelectronics Technologies 2020 (ENIAC), the Hydrogen and Fuel Cells Initiative (FCH) and the Innovative Medicines Initiative (IMI), are interesting as they offer platforms to conduct demanding research and technology programs. The JTIs have already been developed further and the use of the LMI instruments may be too late. One member of the Commission staff explains: *"The LMI supports other initiatives, but, for example, with JTIs, it is too late. In the Innovation Partnership, which is one of the key elements in the new innovation strategy, current instruments are used instead. It must be mentioned in this context that the Innovation Partnership is not a new instrument but a policy tool in which these current instruments are used."* One officer who has been working with the LMI since the Aho et al. (2006) report reveals that: *"when we were identifying themes the sectors did not raise their hands…As to JTIs, the public private partnership for R&D in embedded systems, Artemis, has been carrying out some standardization activities."* A member of the Commission staff generalizes links between the Framework Programme and the LMI: *"The framework programme has weaknesses related to the LMI because very little has been done. Information Society and Media Directorate-General has been doing something, but I don't know exactly what demand-side policy instruments they have been using…"*

Recently in October 2010, another new strategic approach called Innovation Partnerships was launched to "to streamline, simplify and more efficiently coordinate existing instruments and initiatives and complement them with new actions if needed" (European Commission Communication 2010). This should make it easier for partners to co-operate and achieve results more quickly than now. The partnerships will build upon relevant existing tools and actions and, when applicable (e.g., for Joint Programming and the LMI), integrate them into a single coherent policy framework. While the Innovation Partnerships emphasizes flexibility; there will not be a 'one-size-fits-all' framework. One interviewee elaborated the future of the LMI in innovation as: *"Maybe they (the European Commission) will build the LMI inside these Innovation Partnerships. Since the areas are different, areas of the LMI might be re-considered. This Innovation Union is like an umbrella and so these partnerships will guide the future actions of LMI."*

4.2 Opportunities and challenges of the LMI for bio-based products

The current state of these instruments can be compared from the diffusion of innovation perspective based on Table 1, where the two first attributes, relative advantage and compatibility, are considered as the most important ones. Based on the differences identified in Table 1, relative advantage of the LMI corresponds mainly to opportunities perceived in promoting market uptake of bio-based based products, whereas from policy point of view, related challenges are deriving from lacks in compatibility as well as

complexity and difficulty to co-ordinate different instruments. In Competitiveness and Innovation Programme some demand-side networking approaches have also been used, but their role has not been very significant in comparison to LMI, and Joint technology Initiative has traditional technology orientation. Regarding compatibility, it is not possible draw clear conclusions regarding LMI in comparison to Competitiveness and Innovation Programme or Joint technology Initiative because of its newness and lacking budgetary figures. Overall, the characteristics identified suggest both scope for and a need for actions to be streamlined in order to enhance especially coordination and the implementation phases of the European Union innovation policies on the bio-based sector.

In the following we will discuss further the relative advantage, compatibility and complexity of the LMI, respectively, but mainly as based on the evidence from expert interviews. From the view of relative advantage, one member of the Commission staff describes the role of the Lead Market Initiative in the new innovation strategy: *"demand-side instruments are linked to research projects, which is new. In the Lead Market Initiative, it was possible to test these demand-side instruments and now these policy tools are supposed to support other policies…Most previous EU policy initiatives have focused on supply side measures which tried to push innovation. Demand-side measures give markets a greater role in 'pulling' EU innovation by providing market opportunities. Initial steps have been taken under the EU Lead Market Initiative, but a bolder approach connecting both supply and demand sides is needed."* On one hand this expert showed a strong belief in the efficiency of demand side innovation policy, but also showed scepticism whether the coordination between demand and supply side policies in case of the LMI for bio-based products is yet sufficient.

Secondly, there was concern on how to move on with the creation of markets and what will be the foundation of pricing of the new bio-based products. A Commission officer defines the greatest challenges implementing LMI on bio-based products as: *"Are we really willing to pay for these kinds of products? What affects pricing? For example, good standards tend to decrease the prices… Pricing in public procurement, especially in green public procurement, also includes these environmental aspects. Because of the lack of raw material these products tend to be expensive and the prices of agricultural products tend to fluctuate a lot. If we succeed in having good regulation, investments will increase."*

Third, the challenge remains regarding simultaneous coordination of various policy instruments. Also according to Ahvenharju et al. (2010) whereas it is possible to affect demand in many fields by using public policies, it is still unclear what principles one should use to select the innovations and solutions, or markets which should be advanced, for example, with standards, and at the same time, what are the effective public resorts. Ensuring coherence and coordination of activities between policy-makers in the Member States (including procurement agencies and standardization bodies), Commission services, businesses and other stakeholders, such as NGOs and consumers, is clearly crucial to the success of the LMI (Mid-term progress report…2009b). They also suspects that the sectors defined in the LMI are perhaps too broad from the domestic perspective, which makes coordination task a complex and challenging one. According to Ahvenharju et al. (2010), this calls for active connection of the LMI to domestic policies of the Member States.

5 Discussion and conclusions

The LMI is the first comprehensive effort towards a coordinated policy approach based on the demand-side innovation policy in Europe, hoping to accelerate time-to-market of bio-based products and services (European Commission, 2007, 2009a and 2009b). As our research question we analysed whether the LMI adequately addresses these challenges, and what areas of improvement can be identified? According to our analysis, the opportunities embedded in the LMI are multitude in promoting innovation and new product development of bio-based products, but so are the main challenges of the LMI on bio-based products including more efficient combination of supply and demand side policy instruments, creating transparency at national and transnational level, and better coordination between various policy instruments. As the LMI type of approach could in the future, if continued, prove to be an important platform in helping to bridge the gap between the demand and supply side of innovation policy through generation of new technologies and advancing market penetration of the new products. Over the long run the greatest positive effects of European Union innovation policy on bio-based products may emerge not only from better co-ordination, but

also through creating new learning networks and bilateral contacts across policy areas, actors (such as. mobilised public procurers and standardisation organisations), as well as across various sectors and the European Commission services.

However, as an answer to the second part of question, in this particular case, the diffusion of new products seems to be particularly dependent on overcoming the problems of critical-mass markets and a fragmented supply side. Unfortunately the weak co-ordination and lack of complementarity between different other EU initiatives for bio-based products has so far to some extent probably inhibited timely implementation of these measures. An interesting exception can be found in area of the biorefinery technology, mainly boosted by the ambitious targets of the European Union Energy and Climate Policy towards 2020. The absence of standards and certification systems has hindered the market update of bio-based products, and using several related policy initiatives has been so far relatively inefficient in speeding up the time-to-market.

Methodologically, as a limitation of this study, one might question the applicability of Roger's innovation attribute typology (2003) when analysing a larger industry level initiative. However, it was found to be relatively applicable in empirical analysis, although information on some other initiatives presented in Table 1 could have been more comprehensive, facilitating a more in-depth analysis of underlying similarities and differences between instruments. We also excluded from our analysis the role of legislation, which can be seen as a shortcoming.

However, despite the number of interviews in the study being small, the data and findings drawn from it saturated during the research process, so that even the present sample was likely to be sufficient (Yin, 2003). Although interview material covered all research questions, more interviews would have been useful from a broader perspective, including representatives from other EU Member countries to facilitate more in-depth analysis of potential domestic implementation issues and challenges.

In order to further evaluate the success of the Lead Market Initiative and to discuss the future of bio-based products markets at European level, we recommend further research on the subject after the end of the initiative, even though not all impacts are likely to materialize in the immediately coming years. In the future research, challenges in particular related to legislation issues of creating lead markets should be considered. An interesting question is also if the relevant diffusion attributes can be assumed to be identical for the different groups of lead users, namely the public sector, private enterprises and consumers (see recently, e.g., Schreier and Prugl 2008), but answering this question would require empirical analysis of antecedents of becoming a lead user by different user groups. Finally, in order to build a more coherent picture of the various initiatives directed to activating innovations in the EU the study, a supplementary study which would focus more deeply on the various institutes' and stakeholders' views could be considered. In doing so, a multidisciplinary approach to R&D&I subjects is essential, as the initiatives rarely focus just on one sector or range of products in the economy.

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Practitioner's Section

Sources of information for technology intelligence in chemical formulation

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This article delineates the chemical formulation field and presents the sources of information, formal and informal, related with technological intelligence in the design of chemical formulations. Furthermore elements are provided for technology strategy integration through the formation of technological maps. In addition relevant databases and web sites were identified: scientific, intellectual property, as well as industry and enterprise specific databases. A technologist must have a panoramic view of the information available and an understanding for the databases structure to conduct the required tests by using Boolean Searching techniques and taking advantage of iterative search strategies. With this, a technologist can choose those sources that are pertinent to chemical product formulation research projects.

1 Introduction

Intelligence is defined as the capacity to obtain and analyze information which facilitates decision making (Cohen, 1999). Technology intelligence (TI) detects opportunities based on early identification of emerging technologies or white spaces pertinent to a company's business interests. Moreover, it surveys the competitive landscape to identify areas with limited or no competition, which corporate strategy can exploit. Competitive intelligence (CI) tracks competitor activities to spot threats early; competitive technical intelligence (CTI) blends elements of both. Porter (2005) described a "tech mining" approach to generate CTI. Tech mining addresses managerial issues by deriving empirical knowledge, primarily from patent and research publication abstract databases. This article extends the resource base to be mined to information from the suppliers, book editors, norms and regulations available through the internet.

Technological intelligence systems have become a fundamental tool for organizations that manage R&D and innovation projects. The UNE166006:2006 EX (standard–Management of R&D and innovation: technological surveillance systems) systematizes the manner in which this activity is set up within innovation organizations. Muñoz et al. (2006) describe the main processes required for the efficient development of this activity by information management professionals.

For the technology intelligence focus on chemical formulation presented here, we refer the reader to two references: the first one is related to the chemical formulation domain (Aubry and Schorsch, 1999). The second one, related with the field of technology intelligence, is Benavides and Quintana (2006). In effect, to avoid useless repetitions, we will take for granted that the person that wants to be familiarized with the techniques of technology intelligence in chemical formulation already knows the mechanisms of the formulation on one side, and the principles and tools of technology Intelligence on the other. This focus will enable us to go in this article to the essential thing, and to present the strictly necessary complements for the specific sources of information and development of technology Intelligence in chemical formulation.

1.1 Some considerations regarding surveillance and chemical formulation

Chemical formulation, still considered today to be an art, increasingly needs a great quantity of multidisciplinary knowledge and has a multisectorial application. The term "formula" here does not refer to the molecular structure but the composition of

a mixture of chemical components which is often complex. In fact the formulation consists of the combination of several "active agents", and some auxiliary components that allow the mixture to have the precise charges, to satisfy a need - real or created - of a consumer. In general, the chemical design problem starts with a basic definition of the product's requirements and sets out to identify a chemical candidate that satisfies a specified set of properties and property values (Cussler and Moggridge, 2001).

The design of chemical-based consumer products, such as specialty coatings, detergents, personal care products and cosmetics, can be largely characterized by efforts to satisfy a unique combination of factors. Several examples of chemical product design approaches can be found in the literature (Hill, 2004; Ng et al. 2007; Wibowo and Ng, 2002) that may include empirical modeling of product properties. Models and simulations may be available but in many cases the formulation process had to be carried out in a design space that is multi-dimensional and difficult to conceptualize.

In the practice, formulation was initially centered on the basis of natural products, but soon organic synthesis the manufacture of new products with very specific physical and chemical properties, which takes us to another function of technological intelligence in this field: the scouting the suppliers of ingredients.

Finally, other aspects should be taken in consideration, such as the price of the active and auxiliary (functional) materials, shelf life, and preparation time (as determined by physical processes of dispersion, mixture, heating or cooling, etc.).

1.1 Principal industrial fields included by chemical formulation

Structuring the chemical industry around two variables, tonnage and formulation (OPTI, 2004), chemical production is broken down into four groups (see Table 1). The Formulation Chemistry subsector comprises Branded Commodities and a large share of Specialty Chemicals (as shown in the green-

Table 1 Industrial Fields in the Chemical Industry

Type	Definition	Manufactured and sold in amounts	Prices
Fine Chemicals	Pure and defined chemical substances, both intermediate and active principles, of high added value.	Less than 10 or 20-ton drums and smaller capacity containers	usually over 3 €/kg
True Commodities	Chemical molecules, highly pure, usually manufactured by a continuous process (ethylene, polyvinyl chloride, sulphuric acid, sodium hydroxide, chlorine, etc.).	Bulk selling	Less than 3 €/kg
Branded Commodities	Mixtures of chemicals of known formulation sold in bulk (household detergents, ornamental paints, cars lubricants, etc.) and in general, products for chemistry consumers.	Sold in bulk	Less than 3 €/kg
Specialty Chemicals	Mixtures of chemical compounds of high value (added cosmetic products, resins, surfactants, additives, dyes, and perfumes, generally speaking) Mixtures of chemical products for use in different chemical industrial processes (textiles, tanning, paper, metallurgy, steel making, construction, water treatment, etc.) as well as other non-chemical processes	Less than 10-20 tons in drums and small capacity containers	In excess of 3 €/kg

shaded areas). This classification will serve as an approximation to the databases.

Specialty Chemicals, also called functional chemicals, are complicated systems and formulations consisting of various components that sell because of their application-relevant properties. As opposed to commodities and fine chemicals, the customer does not purchase molecules, but rather an application-relevant effect; the product performance is achieved by means of targeted design of molecule systems. As a result of this development, the customer is provided with a "high impact additive" which has a very good price-performance ratio and which provides the essential component of his product.

The customer's requirements dictate the development of products and therefore very special customer-specific solutions will be developed in close cooperation with the customer. Because of this, functional chemicals can be described as problem solvers. The products that are developed cannot simply be substituted with competitors' products; in other words, the cost and risks associated with product substitution are high for the customer. Decisive for the successful marketing of the products is the kind of technology applied, and the implementation of targeted development of a solution specifically tailored to the customer's needs.

The formulator may also routinely access databases in search of previous formulations as well as make use of mathematical models. Design for preformulation development includes statistical design of experiments, allowing simultaneous evaluation of multiple factors and evaluation of interactions between factors. It is crucial to use advanced biophysical characterization techniques to evaluate the conformational stability of large molecules in addition to traditional methods for evaluation of chemical stability.

The implementation of intelligent software can also lead to significant improvements in knowledge generation and protection of intellectual property, cost reduction, training consistency, and improved communication. Rowe and Roberts (1998) reviewed the applicability of expert systems, neural networks, genetic algorithms and other intelligent software in product formulation for applications ranging from agrochemicals and aluminum alloys to pharmaceuticals and textile finishings, including an explanation of the technology involved and examples of two commercial software packages specifically developed for product formulation.

Based on the preceding considerations we can suggest that the scouting will be much easier to perform if those in charge of executing it have already been employed in the area of chemical formulation. The necessarily implied analytical effort, accounting for the available sources of information in one or more fields of application, will ensure, besides the basic principles, the functionalities that it is necessary to take in consideration.

In this way, in relatively classic services of intelligence, the specializing documentation can be an important contribution. In the case of chemical formulation, the technologists themselves must perform the searches. The role of their knowledge in selecting sources of information, recognizing weak signs, analyzing the patents, etc., acquires utmost importance. It is then a field where tacit knowledge plays an important role. This also means that in the organizations where this tacit knowledge could be transferred, it becomes favored within the frame of informal information.

2 Strategic technology intelligence

After choosing a narrowly defined, strategically important topic, this is constituted as a technological front. The technologist will then proceed to carry out the "exploration route or technological intelligence" to arrive at the available information upon said topic. The route of exploration includes the following steps (at least):

A. Aim for a professional level of knowledge. A1. Compiling the catalogues of suppliers and competitors. A2. Identifying competitive advantage attributes. A3. Finding out the pertinent national and international norms and regulations. A4. Understanding the books and articles related to the front. A5. Determining the suppliers' knowledge. With all this information the technologist would be able to draw a map with the main technological dimensions and its professional marks, and to set the technological position of the business with regard to the most capable international competitor in each dimension. (See Figure 1).

B. Discern the limits of the knowledge frontier. B1. Reviewing existing discussions around new international norms and regulations. B2. Compiling and analyzing patents. B3. Compiling scientific and technological articles and locating them on the map.

C. Envision possible directions for knowledge advancement: C1. Making inferences about the dimensions which technological advance is likely to affect. C2. Consolidating the net of consultants, mainly with expert university research assistants C3. Performing technology and market forecasts. C4. Simulating

Figure 1 Technology Map

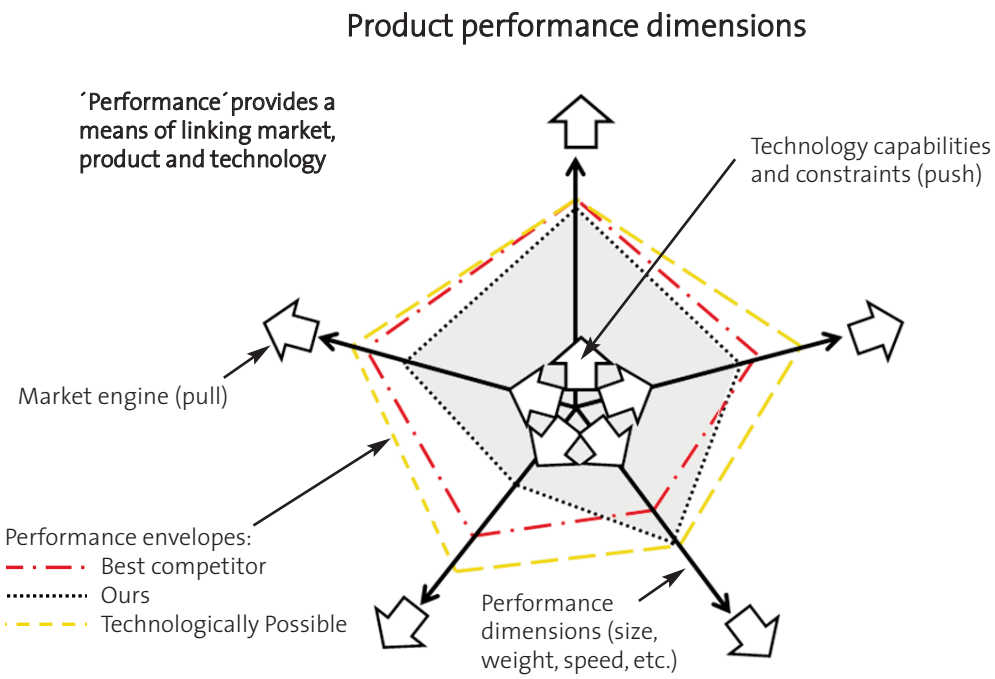
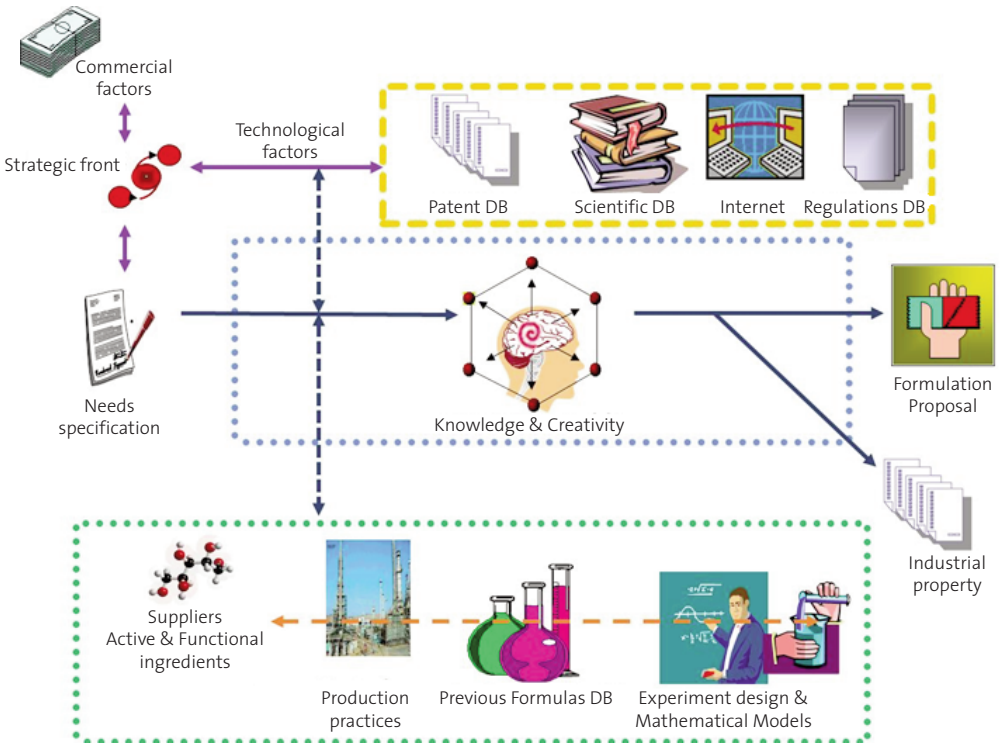


Figure 2 Chemical Formulation Information Flow



relationships among variables to increase the value of their dimensions, including finding relevant variables to measure and to define their relation to one another so they can be manipulated to predict their behavior. C5. Carrying experiments to verify hypotheses.

Figure 2 illustrates the information flow in this process. The first step in knowledge acquisition is to collect all the potential sources of knowledge. These include written documents, i.e. books written specifically in the domain, research and technical reports, reference manuals, case studies, and even standard operating procedures and organizational policy statements.

3 Sources of formal information

3.1 Scientific and technology publication databases (nonpatent)

Following is a non-exhaustive selection of the principal databases that are linked to chemical formulations. In order to exploit this list, it is necessary to relate each chemical specialization with a specific database. For a more advanced analysis, the reader should review in the catalog of that database its description, coverage, frequency of update, etc. For this, it is essential, starting from what we want to do, or the specific products investigated, or the physical-chemical interactions considered, to formulate one or various terms of search from different databases. From the results obtained a selection of the pertinent terms can be made. It should be borne in mind that the diversity of the formulation field and its transversality means that there is not a specific database in the area of formulation.

- CAS (www.cas.org), a division of the American Chemical Society, is the most authoritative and comprehensive source for chemical information.
- The CrossFire Database Suite (info.crossfiredatabases.com) consists of Beilstein, (organic chemistry), Gmelin (inorganic and organometallic chemistry), EcoPharm (pharmacology) and Patent Chemistry Databases.
- Based on The Landolt-Börnstein Database, Springer provides a resource for Physical and Chemical Data in Materials Science (www.springermaterials.com).
- Chemseer (www.chemseer.com) offers a diary of chemistry conferences occurring throughout the world. Also included are a number of valuable resource tools for chemists, including links to online chemistry and chemistry-related journals, links to some chemistry-related companies, chemistry related societies (www.chemseer.com/societies/societies.shtml) and to UK academic establishments.
- CambridgeSoft's ChemFinder (www.cambridgesoft.com/databases) searches hundreds of internet sites via a chemical name, CAS Registry Number, molecular formula, or molecular weight.
- There are many other sources of chemical information on the internet. Useful in discovering new ones are comprehensive guides to chemistry resources on the net, such as Chemdex (www.chemdex.org) or ChemIndustry.com (www.chemindustry.com). Whereas the University of Liverpool's links for chemists (www.liv.ac.uk/Chemistry/Links/links.html) claims access to over 8000 sources. Knovel (www.knovel.com) provides information on a range of topics, including material selection and tolerances, heat transfer, coatings, corrosion, hazard related properties, environmental impacts, industrial hygiene and energy efficiency.

A selection of web sites with databases relating to the formulation of chemical products is:

cds.dl.ac.uk/cds

depth-first.com/articles/2007/01/24/thirty-two-free-chemistry-databases

www.cambridgesoft.com/databases

www.chemistryguide.org/chemical-databases.html.

www.ddbst.com/en/online/Online_DDB.php

www.csa.com/e_products/databases-collections.php

www.dialog.com

www.ovid.com/site/products/index.jsp?top=2

www.science.co.il/Chemistry-Databases.asp

www.symyx.com/products/databases/index.jsp

zusammen.metamolecular.com/2009/03/09/sixty-four-free-chemistry-databases-serialized

We encourage the technologist to refer to other providers in order to obtain the corresponding list of databases and description.

It will be necessary to single out the databases that contain norms and regulations, especially those related to environmental issues, since they will limit the use of certain products in the formulation. We find in this list, besides types of chemical products, information about industrial, legislative, and environmental aspects of marketing and industrial property. We might also observe that if the databases are differentiated, there exist those linked to basic research (Chemical Abstracts, Inspec, Medline, Biosis Previews), and those linked to applications (Rapra for the polymers, Paperchem for the paper industries, WSCA for Coatings, etc.).

Sometimes it will be difficult to investigate the topic in the database. The following guide will save time in the search:

1. Begin with the Database subject guide.
2. Choose a subject area.
3. Start from the list of "key resources".
4. Read the database descriptions to decide which one to search. (Find out about update speeds, coverage, references format, if it provides summaries, keywords and descriptors.) Sometimes, you will have to search in two or three databases to find all the information you need.
5. When that is done, it is necessary to formulate keyword searches. From the obtained results a selection of the most pertinent databases could be done.

Example:
If one is interested in paints, the keyword "coating" may be used to search in the list of a commercial provider (for example Dialog http://support.dialog.com/publications/dbcat) for the databases that can respond to our search. We obtained, mainly:

- PRA's journals (www.pra-world.com/business_services/journals), specializing in up-to-date information on surface coatings worldwide.
- Encyclopedia of Polymer Science and Engineering (onlinelibrary.wiley.com/book/10.1002/0471440264).
- Smithers Rapra (www.rapra.net).
- TOXNET toxnet.nlm.nih.gov, providing access to a cluster of databases on toxicology.
- Advanced Polymers Abstracts (www.csa.com/factsheets/ema-polymers-set-c.php).

3.2 A special database: Chemical Abstracts

Chemical Abstracts Service (CAS) is the world's most important abstracting and indexing service for chemistry and related disciplines. The main databases include Chemical Abstracts, which contains over 32 million document records from the chemical journal and patent literature, and the CAS REGISTRY, for substance information, which contains more than 54 million substance and 62 million sequence records.

SciFinder is integrated with STN's ChemPort Connection, which in turn links to the participating publishers' web sites for the full-text electronic journals[1]. It is the most thorough way of hunting for premium data because of the quality of their indexation and the coverage of the database. In fact, it systematically indexes most of the journals linked to formulation owing to its increasingly interdisciplinary nature. It takes into account chemical, physicochemical and sometimes biological aspects (for example Biosis).

Many electronic journal articles can also be accessed directly via the web from the references retrieved with SciFinder, provided the user is a subscriber to the journals. For more information on this subject it is necessary to consult the "Chemical Abstracts learning center" (www.cas.org/products/scifindr; www.cas.org/products/sfacad).

3.3 Searching on databases

Databases are elaborated by different agents and therefore, the indexation methods, the key words used, and the codes, vary among them. Thus, it is often difficult to know all of them. By using Boolean Searching techniques, compounded with an understanding of database structure, and taking advantage of iterative search strategies, a searcher can use these systems to isolate technical intelligence which may otherwise be overlooked. Use of finder files is an essential part of a searcher's arsenal. In order to become confident in our surveillance, and especially to carry out tests, we advise to choose a body of pertinent references, then to dig up the same references in new databases by using different search strategies. Thus, by comparison, a good notion can be developed of

1) The CAS Source Index (CASSI) Search Tool cassi.cas.org is an online resource intended to support technologists and librarians who need accurate bibliographic information. Use this free tool to quickly identify or confirm journal titles and abbreviations for publications indexed by CAS since 1907, including serial and non-serial scientific and technical publications.

how indexation works and of ways in which searches can be refined.

3.4 A special database: Chemical Abstracts

The patents are an essential information source in the domain of formulation. In fact, they allow connecting the research to the industrial plan. Bios provides a roadmap of U.S. Patent No. 5,723,765 (www.bios.net/daisy/bios/204/version/live/part/4/data) with explanatory text of the purpose and goals of each section. The U.S. patent is used as a model because of its well-ordered structure and because its format is similar to patents in other major jurisdictions (e.g., Europe).

The industrial property databases from commercial suppliers can become prohibitive for the small companies. In this perspective, usage of free databases on the internet is a better solution to facilitate the research and the downloading of the results. A directory of them is at www.wipo.int/directory/en/urls.jsp. These free databases make it possible to run key term searches (an idea, a product's chemical name, data about a medicine) in an accessible manner. In our case, we generally use Espacenet (ep.espacenet.com/?locale=en_EP) and PATENTSCOPE (www.wipo.int/patentscope/en). But effective manual consultation of these databases is often long and does not allow to perform automatic analyses. For this reason (and to this effect), there exists software that affords automatic consultation of the databases (Porter and Cunningham, 2005 p.361), allowing for the creation of local data, and the simultaneous production of statistic representations.

The patents themselves do not feature any key words. Therefore, their interrogation is special. For example, in the case of the Espacenet database, it is necessary to use terms that are present both in the title and in the abstract (always in English), classifications more or less truncated. The international classification of patents (IPC) is the most widely used. The European classification (EC) is more specific and it is rooted in the IPC (but uses more digits). One is often driven to use a mixture of classification and general terms, such as applicants, assignees, inventors, filing date, priority date and patent number.

The International Patent Classification (IPC)[2] system is organized hierarchically into sections, classes, subclasses and groups (main groups and subgroups), for the classification of patents and utility models, according to the different areas of technology to which they pertain. If one does not know the classes and wants to look for application domains, one can interrogate by using free terms from the summary or title and then obtain the relevant classes. There is an IPC natural language search at www.wipo.int/tacsy. Some advantages of using IPC searching are more complete results than text searching, independent of the language of the text and of changes in terminology. The main disadvantages are e.g. a more complex structure of classifications and the requirement of studying classification rules. We made a general search from the software PATENTSCOPE® Search Service (www.wipo.int/patentscope/en). Table 2 shows the global IPC classes involved in the 147260 patents results of searching in PCT for: chemical AND formulation.

Patent information is downloaded from the USPTO and Espacenet databases. With this information, a local database of the project is produced. Software for patent analysis allows selections, presentations and possible correlations (histograms, graphs, charts and nets) to place the search in its context and to obtain the necessary information for the key patents. We show some accessible treatments in the following paragraphs.

For example, applicant expertise correlation can be established if a matrix between applicants and IPC is built and a network of expertise is drawn from this matrix. In the same

Table 2 Some Results from Patent Scope on the Search: Chemical and Formulation

Offices		MAIN IPC									
Name	No	Name	A61K	C07D	A01N	C07K	C12N	C11D	C07C	G01N	C08G	C12Q
PCT	147260	No	50471	12927	6449	5793	4095	3858	3820	3023	2980	2281

2) Assistance in the use of the Classification can be obtained in http://www.wipo.int/export/sites/www/classifications/ipc/en/guide/guide_ipc_2009.pdf

way, networks of applicants (when several applicants appear in the same patent) will show the related companies, etc. For instance, applicants may be correlated with IPC, which will produce a competency matrix, this allows determining the set of competencies of an applicant company in the field, or that of an applicant corporate group, determined by comparison of the common competencies and contrast between different ones.

A matrix of IPC against IPC will reveal the technological network of common patents; inventors with inventors will give the inventor network; and inventor with IPC will give the inventor competencies. Other comparisons can be made by cross-linking the set of available fields: applicants – inventors (what works and where), IPC - date of publication (technologies of the public domain), applicants - date of publication (applicants concerned with technologies of the public domain), etc. Working this way will also make it possible to develop other databases by keeping the original IPC and combining it with other terms such as different active ingredients or coadyuvants, etc. Dou (2004) shows how innovative thinking, comparisons, and value-maps can thus be achieved.

3.5 Chemistry books and journals related to chemical formulation

Journal abstracts from chemistry publishers such as Bentham, Elsevier, Springer and others, covering over 500 journals can be searched and accessed for free. Search by title and issue, or use the journal search engine for full-text search of abstracts across all journals (www.chemweb.com/journals).

The NIST Chemistry WebBook (webbook.nist.gov/chemistry) contains data on gas chromatography, spectroscopic, ion energetic, thermophysical property, thermochemical for organic and small inorganic compounds, reaction thermochemistry for over 8000 reactions; IR, Mass, UV/Vis, Electronic and vibrational spectra. Data on specific compounds can be searched in the Chemistry WebBook by name, chemical formula, CAS registry number, molecular weight, chemical structure, or selected ion energetics and spectral properties.

Wiley presents information from Journals, Backfile Collections, Online Books, Databases, and Reference Works, including the Encyclopedia of Life Sciences, Kirk-Other Encyclopedia of Chemical Technology and Ullmann's Encyclopedia of Industrial Chemistry (www3.interscience.wiley.com/browse/?subject=CHEM), also available from Current Protocols® Laboratory Methods (www.wiley.com/WileyCDA/Section/id-350192.html).

Other major editors with chemistry references are:

Cambridge University Press Chemistry (www.cambridge.org/us/chemistry)

Chapman & Hall/CRC Press (www.chemnetbase.com)

Marcel Dekker (www.cplbookshop.com/glossary/G486.htm)

Oxford University Press (ukcatalogue.oup.com/category/academic/chemistry.do)

ScienceDirect Elsevier (www.sciencedirect.com)

SciTopics (www.scitopics.com)

Springer Verlag (www.springer.com/chemistry?SGWID=0-135-0-0-0)

3.6 Chemistry books and journals related to chemical formulation

The chemical industry is a highly regulated sector which makes it necessary to be alert to new requirements continuously being incorporated in the formulation designs. The most important include the following:

- REACH is a new European Community Regulation on chemicals and their safe use. It deals with the registration, evaluation, authorisation and restriction of Chemical substances. The new law entered into force on 1 June 2007.
- The mission of the Environmental Protection Agency (EPA) is to protect human health and the environment (EPA's Laws & Regulations Quick Finder: http://www.epa.gov/lawsregs). The chemical and process information component of CTSA (Cleaner Technologies Substitutes Assessment) consists of nine data gathering modules: Chemical Properties, Chemical Manufacturing Process & Product Formulation, Environmental Fate, Human Health Hazards, Environmental Hazards, Chemistry of Use & Process Description,

Process Safety Assessment, and Market and International Information.

- The Food and Drug Administration (FDA) is responsible for protecting the public health by assuring the safety, effectiveness, and security of human and veterinary drugs, vaccines and other biological products, medical devices, food supplies, cosmetics, dietary supplements, and products that give off radiation. Of special interest is the Code of Federal Regulations (CFR), Title 21.
- National offices of standards and regulations, i. e. U.K. (www.bsigroup.com), Spain (www.aenor.es), France (www.afnor.org), Germany (www.vde.de and www.din.de).
- Industrial Chemical Standards, i.e. ASTM (www.astm.org/Standards/industrial-chemical-standards.html), CENELEC (www.cenelec.eu), IEEE (standards.ieee.org).
- The NIST Data Gateway (srdata.nist.gov/gateway) provides access to scientific and technical data produced by the US National Institute for Standards and Technology including free web databases, such as standards for chemical analysis, etc. The TRC Thermodynamic Tables - Hydrocarbons and the TRC Thermodynamic Tables - Non-Hydrocarbons are technical resources used extensively by the petrochemical industry. Authors in technical and scientific journals regularly cite the Tables as a reputable source of evaluated thermophysical and thermodynamic data (trc.nist.gov/tables/trctables.htm).

While no method has emerged as dominant for evaluating and comparing chemical or material hazards, rather there exists a range of assessment methods and tools that are available for defining and comparing the hazards associated with chemicals. The Lowell Center's Chemicals Policy Initiative presents a comprehensive framework for alternatives assessment; and identifies tools and appropriate ways of assisting green chemistry innovation and safer supply chain management of chemicals (www.chemicalspolicy.org/downloads/FinalAltsAssesso6.pdf).

4 Informal Sources of Information

The domain of informal information is also important. Nevertheless, we recommend to validate it before incorporating to intelligence reports. This domain comprises information from symposia, exhibitions, scientific meetings, workshops, reports of industrial corporations, advertisings, catalogs, etc.

4.1 Scientific and technological associations

Scientific and technological associations are of great utility especially when there are approached complex or multidisciplinary fields, since it is possible to rest on sets of competitions. Scientific associations are a way of simultaneously obtaining information and personal contacts. There exist numerous scientific associations that organize congresses, jointly contribute information, produce scientific magazines, etc. Some of them are purely scientific, others have lucrative purposes. A large number of organisations are devoted to formulations –either making or analysing them, providing raw ingredients, manufacturing instruments to study them, creating jobs for formulation scientists, providing training, publishing literature, etc. At any rate, it is good to know them, to analyze their domains of competence and to take part or to monitor their production. Below are a few links from institutions that support or have formulation activities:

- The Societe Chimique de France (SCF), the Institute of Chemical Engineers (IChemE) and the Royal Society of Chemistry (RSC) have established new subject groups focusing on formulation to support both major businesses and the multitude of small businesses active in product formulation, process, design, and manufacture (www.societechimiquedefrance.fr/fr/formulation.html, www.icheme.org/communities/subject_groups/formulated%20product%20engineering.aspx and www.rsc.org/Membership/Networking/InterestGroups/FSTG).
- The DECHEMA Gesellschaft für Chemische Technik und Biotechnologie e. V. is distributing databases (www.dechema.de/en/Publications/Databases.html) covering different aspects of chemical technology, environmental protection and biotechnology. These systems are available as online and in-house databases.
- The Formulation School (UK) (www.formulationschool.com) and The Association of Formulation Chemists (US) (www.afc-us.org) are a virtual cross-linking interface between industry and expertise within universities to help companies working in formulation to search for all the support services they need; contract research,

contract manufacture, contract packaging, training, consultancy, analytical services etc.

4.2 Information from suppliers

Many corporations that sell chemical products or mixtures of chemical products suggest various formulations which include their ingredients and additives. They put them to the service of their potential customers. Many examples exist: www.happi.com/formulary, www.issa.com, www.cspa.org, BASF Formulation Assistance www2.basf.us/performancechemical/bcperfformulation_assistance.html. Synapse information resources (www.synapseinfo.com) constantly update a growing database which includes ingredients and additives of worldwide manufacturers.

4.3 Free Internet Sources

There is a lot of available information on the internet. Note for example the information coming from laboratories of university researches, of special advertisings done for certain products, the forums of discussions, etc. This information, in contrast to the preceding one, will have to be validated.

Example:

The Indiana University School of Informatics built CHMINF-L, an Internet resource for keeping up with new information products of interest to chemists and for getting answers to chemical information questions in general (listserv.indiana.edu/cgi-bin/wa-iub.exe?A0=chminf-l). There are still many examples of good web sites where reliable chemical information can be found at no cost: www2.chemie.uni-erlangen.de/services, http://chem.sis.nlm.nih.gov/chemidplus and www.orgsyn.org.

5 A creative use of technology intelligence

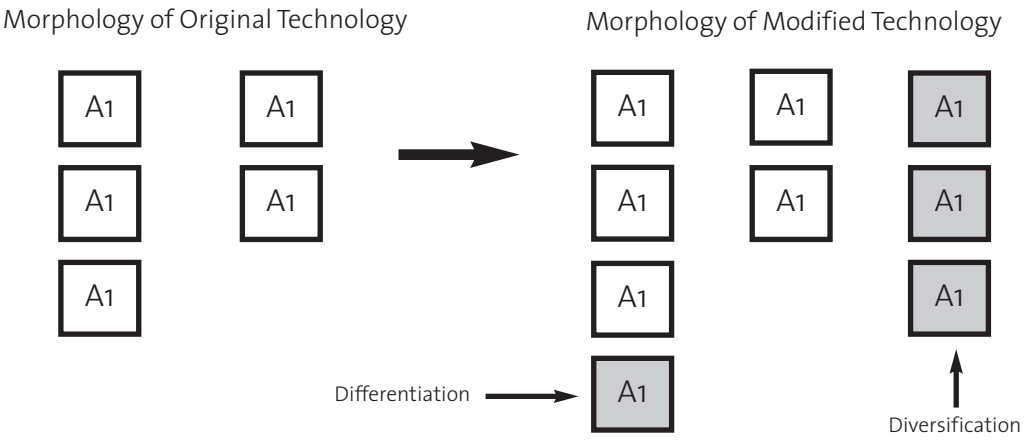
As we have seen, information is the essential ingredient for innovation. With this cognition the technologist will be able to think up ("incubate") other forms of classifying knowledge. Methodologies to apply creative thinking include the following (among others):

Quality Function Deployment (QFD) The procedure consists of five steps: First, the market research was conducted to determine the target segment. Second, the behavioral motives of the consumers in the target segment were analyzed. Third, product objective specifications were established through physico-chemical and instrumental methods. Fourth, sensory analyses were performed involving both consumer and trained panels. The last step of research relates to analysis of the mutual relations between technical and sensory measurements and integration of results in the House of Quality matrix (Seider, et. al 2009).

Systematic Inventive Thinking (SIT). Stern et al. (2006) describe case studies of the application of the SIT method, through the Function Follows Form work process, for the purpose of arriving at innovative product and technological solutions in the chemical industry.

Morphological analysis (Yoon and Park, 2005). The morphological analysis of claims in patents is based on the identification of occupied

Figure 3 Morphology Analysis (Yoon and Park, 2005 p. 151).



configurations on collected patents while the unoccupied configuration territory is suggested as a technology opportunity. Technologies can be analyzed to identify a technological breakthrough by revising the morphology of patents, which is achieved through two methods—differentiation and diversification. While differentiation is related with the extension of shapes, diversification is concerned with the extension of dimensions (see Figure 3).

Chemical formulation patents can be analyzed to identify ingredients in the protected formulation and the behavior (response) of such mixture (see Table 4). Furthermore, with data derived from technology intelligence, similar and substitutive ingredients can be proposed for the purpose of an innovative formulation with intellectual property possibility.

5 Conclusions

Even when we did not develop the technological intelligence within the frame of a specific formulation, a route to obtain desired information was determined as applied within the frame of chemical formulation. It is also necessary to point out that depending on the project that is going to be developed, or the ingredients to be used, the technologist will have to re-cap the information and construct its data base constantly, because of the continuous evolution in this area.

In one sense, constant alertness should be exercised towards products offered by the suppliers of the ingredients, both actives and coadyuvants, as well as towards investigation work, and to competitors' products and packaging systems and applications, due to the fact that all of them have an important role to play in the product's marketing and usage plan.

The transdisciplinarity of the formulation sometimes requires expert feedback. This will in turn require at least two activities: consolidating a net of experts from chemical associations, and managing intellectual property in those cases where exchanging or sharing information is required.

We will do the same step for all the chemical terms in accordance with the schedule of conditions. According to the selected products, we will look at the toxic effects, etc. It should be noted also that it is necessary to search Chemical Abstracts to obtain the results upstream. But in this case the appropriate set of scientific vocabulary is required. We might use selected patents, and having retrieved them in Chemical Abstracts, move towards the fundamental one. It would also be necessary to test the commercial databases present in Dialog or DataStar in the domain of interest.

Technological alertness in the formulation domain will take time and might be relatively complicated, since it is evident that there is inevitable work to do, e.g. by selecting the most important critical factors to monitor.

Last but not least, the competitors' products are a good information source. By reverse engineering their functionality, cost, etc. can be analyzed. While time-consuming, it may in

Table 4 Methylene Chloride Free Paint Stripping Composition (US patent 7087565).

Halogenated hydrocarbon liquid, having more than one atom	Polar oxigenated organic liquid	Hydrogen bondable thickener
Conc. 40-90%	Conc. 0.1-20%	Conc. 0.01-20%
n-propyl bromide	hydroxilated alkanols	alkylated cellulloses
1-chloro-2-methylbenzene	hydroxilated alkenols	alkylated silicas
1-chloro-4-methylbenzene	hydroxilated cycloalkanols	
1-chloro-4-trifluoromethyl)-benzene	hydroxilated cycloalkenols	
1,2-dichloro-4-trifluoromethyl)-benzene	ethers	
	ketones	
	esters	

certain cases be the least risky solution. The importance of the analysis and tacit knowledge of the specialists is then preponderant. The names of the different ingredients that are present in the product considered are also a precious assistance. In fact the legislation, in the domain of the food processing, cosmetics, pharmaceutics, sanitary products, regulate the use of ingredients.

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Practitioner's Section

Working capital management in the Swiss chemical industry

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Introduction

The performance of Swiss based chemical and pharmaceutical companies regarding their working capital management and its underlying components, namely accounts receivable, inventories and accounts payable differs over time and between the single firms. The calculation of a cash potential for the year 2008 shows that 17 billion CHF is tied up in the companies' balance sheets if they would realise the Swiss best practice performance. It has also been shown that in recent years Swiss chemical and pharmaceutical companies have a considerably higher working capital level compared to their European and US peers. The managerial implications for the achievement of best practice are the awareness of the top management, efficient processes on the operating level as well as an enhanced collaboration within the company as well as throughout the entire supply chain.

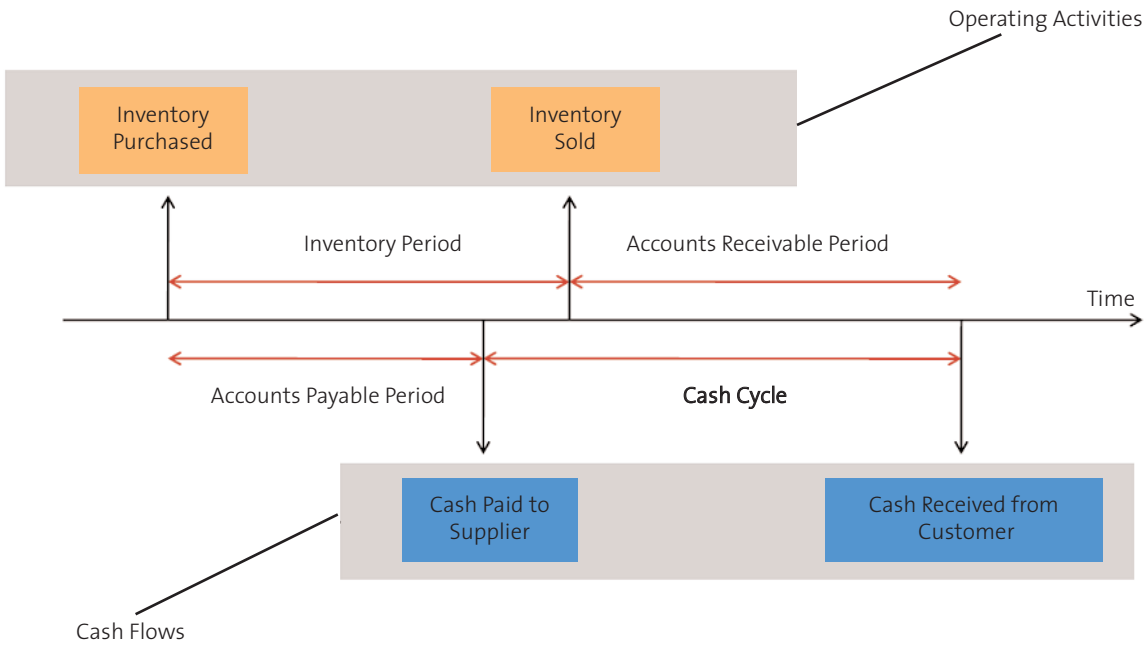
The need for operational excellence

The chemical and pharmaceutical sectors are facing significant changes: the ongoing consolidation in the supplier, competitor and customer base, as well as the proceeding globalization is posing numerous challenges. Moreover, the increasing price competition and rising feedstock prices bring margins under pressure and force the chemical and pharmaceutical firms to seek for ways to oppose those trends. Working capital optimizations offer various opportunities, both in the short as well as in the long run. The working capital mainly comprises accounts receivable, inventories and accounts payable. These three balance sheet entries are the immediate financial picture of a company's operating activities. At this point the relevance of the working capital becomes obvious: it lies at the interface between a firm's daily operations and the short run funding needs of a company. Improvements within the working capital levels thus offer various benefits, like lower capital requirements and lower capital costs, but also optimized supply chains and operational excellence. Eventually, these changes lead to higher profitability and to competitive advantages.

The origin of working capital

The operating cycle is composed of the inventory period and the accounts receivable period place (Ross et al., 2008). The inventory period is the average amount of time the inventory is held, whereas the receivables period is the average number of days it takes from the sale of the goods until the cash receipt from the customer. The accounts payable period, in turn, is the average time span between the purchase of the raw materials and the cash outflow to the supplier.
The difference between the operating cycle and the accounts payable period is called the cash cycle. It is the time period it takes on average from the cash outlay by the firm to the suppliers to the cash inflow from the customer. In other words, it shows the financing needs of a company regarding the operating activities, since part of the inventory and accounts receivable have to be financed by either borrowing money or holding a liquidity reserve (Farris and Hutchison, 2003). The amount of this additional financing depends on the length of the cash cycle: the longer the cash cycle is, the higher are the capital requirements and vice versa (Boer, 1999). This is due to the fact that the longer a firm has to wait after the cash outflow to the supplier to the cash inflow from the customer, the longer it has to finance the operations through other sources.

Figure 1 Operating and cash cycle



Source: Own elaboration, based on Ross et al., 2008

The connection between the operating activities and the financing needs of a company becomes more obvious when considering its impacts on the balance sheet. The length of the operating cycle determines the actual inventory and accounts receivables levels and hence considerably affects the amount of current assets which is held by the company. On the other hand, the length of the ac-counts payable period has a substantial impact on the level of a firm's current liabilities, namely the amount of accounts payable. The capital needs, with respect to the operating activities are finally determined by taking the difference between the sum of the accounts receivable and the inventories minus the accounts payable. This difference is called the net working capital and corresponds to a company's short run financing needs (Wagner and Locker, 2008).

Measuring the working capital

Various ratios can be used in order to evaluate a company's short term assets and liabilities. Well-known examples are the liquidity ratios like the current and the quick ratio (Volkart, 2006). These ratios focus on a firm's short-term solvency, since they provide an indication of how well the short-term liabilities are covered by short-term assets. In other words, they indicate whether a company is able to meet its currently maturing financial obligations by its currently maturing short-term assets, and hence examine a firm's liquidity.

In order to incorporate the dynamic nature of a firm's business the working capital ratios and the cash cycle are becoming more popular (Losbichler and Rothböck, 2008). The Days Working Capital ratio (DWC, also called cash conversion cycle or cash-to-cash cycle) expresses the cash cycle in terms of days, and is calculated based on the lengths of the underlying periods, which are depicted in Fig. 1.

The days sales outstanding ratio (DSO) converts the receivables period into days (Brealey and Myers, 2005):

$$DSO = \frac{\text{Accounts Receivable}}{\text{Sales}} * 365 = \frac{\text{Accounts Receivable}}{\text{Average Daily Sales}}$$

The DSO measures how many days it takes on average from the sale of the goods until the customers pay their bills. A high DSO leads to a longer cash cycle, and hence also to higher working capital levels.

The days inventory outstanding (DIO) denotes the average time span in terms of days for a good to be purchased as raw material, converted into the finished good, and finally sold to the customer:

$$DIO = \frac{Inventory}{Sales} * 365 = \frac{Inventory}{Average\ Daily\ Sales}$$

The sum of the DSO and DIO result in the operating cycle. Therefore, an increase in these ratios leads also to an increase in the cash cycle.

The day's payable outstanding (DPO) expresses the average number of days a company waits until it pays its suppliers:

$$DPO = \frac{Accounts\ Payable}{Sales} * 365 = \frac{Accounts\ Payable}{Average\ Daily\ Sales}$$

Since the cash cycle is the difference between the operating cycle and the payables period, an in-crease in the DPO results in a shorter cash cycle. Hence, the later the cash outflows to the suppliers occur, the less capital is needed to finance the operating activities of a company.

The Days Working Capital is calculated by putting these ratios together:

DWC = Days Sales Outstanding + Days Inventory Out standing – Days Payable Outstanding

The cash conversion cycle thus measures the average time span between the cash outflow for the purchase of inventories and the cash inflow from the collection of receivables.

The importance of an efficient working capital management is confirmed by several studies (e.g. Jose et al., 1996 or Shin and Soenen, 1998), which show that a shorter cash cycle leads to higher profitability and rising share prices thus, resulting in an increased enterprise value.

The working capital survey of the Swiss chemical industry

The survey is aimed to reveal the working capital performance of Swiss based chemical and pharmaceutical companies within recent years. Moreover, general trends and peculiarities of the chemical sector are presented and the corresponding drivers and causes are identified. In addition to this quantitative approach, a questionnaire was forwarded to all investigated companies in order to evaluate the awareness and relevance of an efficient working capital management for the firms and the responsible executives.

Research methodology and scope

The ratios *Days Sales Outstanding, Days Inventory Outstanding* and *Days Payable Outstanding* represent the metric for the assessment of accounts receivable, inventories and accounts payable, respectively. The *Days Working Capital* ratio is considered as measure for the overall examination of the working capital levels, i.e. providing the collaborative working capital view. Year-end balance sheet entries have been used for the calculations of all ratios.

The sample consists of 18 companies that are listed at the SIX Swiss Exchange and headquartered in Switzerland. Furthermore, firms were chosen according to the Standard Industrial Classification (SIC) system: only corporations classified as *Chemicals & Allied Products* (SIC Code 2800) and its sub-segments were considered. Based on those requirements, the study includes the following eighteen firms:

Actelion Ltd., Bachem Holding AG, Ciba AG (now part of BASF), Clariant AG, CPH Chemie & Papier Holding AG, Dottikon ES Holding AG, Ems-Chemie Holding AG, Galenica AG, Givaudan SA, Gurit Holding AG, Lonza Group AG, Novartis AG, Quadrant AG, Roche Holding AG, Acino Holding AG (formerly Schweizerhall Holding AG), Siegfried Holding AG, Sika AG, Syngenta AG

Outliers (mainly start-up companies) have been excluded in order to provide a more accurate view. [1] The five firms below are not considered for the survey:

Arpida AG, Basilea Pharmaceutica AG, Cytos Biotechnology AG, Santhera Pharmaceuticals Holding AG, Speedel Holding AG

The starting data, namely the year-end figures of the accounts receivable, inventories, accounts payable, and sales, was taken from the THOMSON REUTERS OneBanker data base. The working capital performance metrics are thus calculated based on publicly available financial statements issued by the companies. Although the study focuses on firms headquartered in Switzerland, the individual figures correspond to their respective global values.

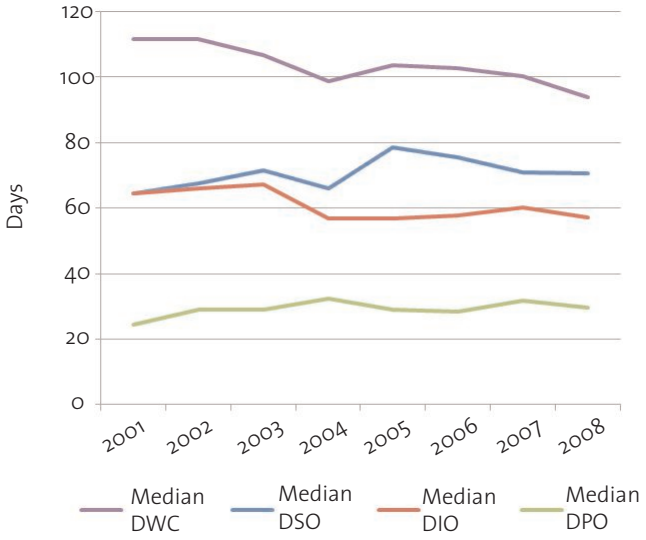
values.

Receivables performance

There is no clear trend regarding receivables performance within the last eight years: the Days Sales Outstanding (DSO) median followed a very volatile path and there have been great

1) Start-up companies usually are quickly expanding and have less constant sales volumes. Therefore, working capital levels and turnovers sometimes vary considerably from year to year, and hence also the measured ratios (DSO, DIO, DPO and DWC). Furthermore, since those firms are growing very fast, the processes are not very harmonized and thus not suited for comparisons with established companies.

Figure 2 Overview ratio evolution 2001 - 2008



Source: Thomson Reuters, based on publicly available financial statements

fluctuations even between certain single years, as displayed in Fig. 2. Overall, the DSO median has deteriorated within the last eight years by 5 days from 65 days in 2001 to 70 days in 2008. That corresponds to an increase of 8%.

The greatest increase occured during 2005, when the median went up by 19%, in accordance with the fact three quarters of the firms displayed a higher DSO value in 2005 compared to 2004. In the light of this industry-wide deterioration, it seems that there existed external causes which put pressure on the entire sector. Actually, the economic circumstances were hard in the years 2000 to 2005: the Swiss economy was suffering heavily from the impacts and aftermath of the Dotcom bubble. The recovery of the economy in the third quarter of 2005 is likely to be the cause of the rise in DSO. The chemical and pharmaceutical companies have probably tried to achieve more sales volume and to bind their customers by agreeing to less rigorous payment terms and hence longer payment periods.

The trends towards consolidation and globalization supposedly are other factors that have caused stagnating or even rising DSO figures: the consolidation phase has led to bigger customers in terms of sales volume. It is likely that the power has shifted to the buyers and that more pressure is put on the suppliers in order to negotiate longer payment terms (Budde et al., 2006). Moreover, the globalization has led to a geographical shift of the customer base, mainly to Eastern European and Asian countries. That entailed changing customer relationships and threatened established supply chains. Probably, the management did not want to endanger those sensitive relationships by forcing stricter payment terms.

Inventory performance

A lean inventory leads to less tied-up capital and less inventory costs. Therefore, a lower Days Inventory Outstanding (DIO) ratio leads to less capital requirements and higher profitability. The Days Inventory Outstanding (DIO) median value has improved over the whole period by 11%, since it has decreased by 7 days from 64 days in 2001 down to 57 days in 2008. Despite this respectable overall lowering in inventory levels, the study results imply no constant and ongoing improvements for the whole sector: in fact, the DIO median has risen in years 2001 to 2003, substantially declined in year 2004, but has stayed almost unchanged until 2008. However, there has been a decrease of 3 days in 2008, which at least shows a positive trend in the recent past.

As mentioned above, the economy was slowing down in years 2001 to 2004, and it is likely that this downturn has led to an optimization within the inventories. The companies reduced its stocks in the light of

decreasing sales and bad business prospects. That led to declining DIO values across the entire industry. However, although the economy recovered in the second half of 2005, the DIO median shows no considerable increase. The companies obviously have been able to increase their sales by keeping the production lean. In 2008, the decrease in the median might be again partly due to the bad business outlook.

Furthermore, a study of the consulting company KPMG (KPMG, 2008) has stated that most of the improvements regarding the inventory management were most likely achieved through a

"*[...] continual investment in the manufacturing process to improve yields, remove bottlenecks and accelerate production.*"

KPMG mentions in the same report that the companies have tried to transfer the responsibility of the raw material inventory to the suppliers. That happened for example through the creation of consignment stocks[2], and hence led to lower inventory levels in the firms' balance sheets.

The two main trends stated in the DSO chapter, consolidation and globalization, also give rise to new challenges with regard to the inventory management. Supply chains are becoming more and more international, e.g. through the outsourcing of certain activities or the global purchase of raw materials, resulting in a lengthening of the supply chains (Christopher, 2008). Moreover, new supply chains arising from mergers and acquisitions have to be developed and integrated.

Another impact on the inventory performance originated from the constantly rising raw material prices, like crude oil, natural gas and petrochemicals. Not surprisingly, the chemical industry suffered more from increasing oil prices than other industries. The high oil dependency lies in the nature of the chemical and pharmaceutical production: oil is the basis of virtually every organic product. A price inflation in raw materials leads to higher inventory levels in monetary terms, because the same amount of stock keeping units has a higher value.[3] The effect of the rising feedstock prices on the inventory performance, measured by the DIO, partly depends on a company's ability to pass on these higher costs to its customers, namely through price increases of the products (Ernst & Young, 2008). Since the DIO compares the inventory level with the daily sales, the relationship becomes apparent: only if the sales volume increases equally to the inventory level, in relative terms, the DIO will stay the same. However, that not only requires a full shift of the higher costs to the customer, but also the same sales volume in terms of units despite the price increase. It is likely that most of the companies have not been able to fully pass on those increases to their customers in the short-run.[4] Therefore, the rise in feedstock prices most probably had a negative influence on the industry's inventory performance, except for the year 2008. On the other hand, the considerable fall in the oil price in 2008 might partly have caused the decreasing DIO figures for the median.

Payables performance

In contrast to the DSO and the DIO, a higher Days Payable Outstanding (DPO) ratio leads to lower net working capital levels. In other words: rising DPO ratios mean an improvement, whereas falling DPO ratios indicate deterioration.

The DPO median exhibits an overall upward trend, with a temporary downfall in the years 2005 and 2006. Overall, it has increased by 5.5 days or 22% from 24 days in 2001 up to 29 days in 2008. In the year 2008 however, the median again has fallen by 2 days, which means a negative tendency for the recent past. The economic circumstances seem to play an important role also with regard to the payables performance. The median increases in years 2001 to 2004, which leads to the assumption that the companies have stretched their accounts payable by later payments to their suppliers. This is in accordance with the fact that the median has declined in 2005, when the economy experienced an upturn. The median decreased in 2008 after an increase in 2007. Since the raw material prices have risen sharply in 2007 and the first half of 2008, it is likely that the companies have recently focused on the price rather than on the payment terms.

As mentioned above, the sector has experienced a consolidation and globalization phase (Jakobi, 2001). Whereas those trends can threaten the receivables performance, it also provides chances regarding the payables performance. The increasing size of the firms within the chemical and phar-maceutical

2) Inventories held in a consignment stock belong to the supplier until the customer uses them. In other words, the stock legally belongs to the supplier, but it is held by the customer. The customer has the advantage that the stock is stored at the production site, but the inventories do not appear in its balance sheet.

3) This is true for the raw material fraction of the inventory. The valuation of the WIP and finished goods may also depend on market prices.

4) Since a firm's negotiation position is enhanced when the raw material prices are staying at higher levels, it is more likely that the higher costs can be passed on to the customers in the long run. The effect on the inventory performance should therefore be mitigated in the long term.

industry, resulting from various mergers and acquisitions, increases the supplier's dependency on the customer, and leads to more power for the buying firm with regard to the negotiations of payment terms.

Nevertheless, the overall rise is probably also partially caused by the price inflation of the raw materials. The mechanism is the same as for the DIO ratio: the increasing feedstock prices lead to higher accounts payable. Since it is not likely that the entire increase in raw material costs has been transferred to the customers, the rise in DPO is probably partially caused by the rising feedstock prices.

Collaborative working capital management performance

The Days working capital (DWC) ratio is used as a measure of the overall working capital manage-ment performance. The DWC combines the values of the different working capital components (DSO, DIO, and DPO), and serves as a measure of a company's net working capital level in general.

The DWC median shows a clear downward trend within the last eight years and hence, the working capital levels have been lowered overall. Since 2001, the industry's median has decreased by 17.5 days from 111 days in 2001 to 93.5 days in 2008, an improvement of 16%. This is supported by the fact that eleven firms out of eighteen exhibit a lower Days Working Capital ratio in 2008 than in 2001.

Since the collaborative working capital measure DWC is composed of the underlying components' ratios DSO, DIO and DPO, the DWC evolution is the result of the evolution of the single underlying ratios. Hence, changes in DSO, DIO or DPO cause a change in DWC. As described above, the economic situation has a big influence on the single components of the working capital. The same is true for the DWC median, which has decreased during the years 2001 to 2004, when the economic circumstances were difficult. It increased in 2004 when the economy was recovering, and declined again in the years afterwards. This connection implies that the firms are focusing on working capital management in times of difficult economic conditions and somehow neglect an efficient working capital structure in times of an upturn. Since it is harder to generate profits or obtain credits when the economy is slowing down, companies try to run their businesses by internal funding and improve the operating results through even stricter cost reduction programs. On the other hand, the firms focus more on market share and gaining sales volume during promising economic outlooks, and hence set different priorities, which leads to a losing focus on the cash cycle.

However, the amounts of net working capital have been lowered again after the achievement of the new production level in the years 2006 and 2007, when the firms have been accommodating with the new output level. In 2008, the DWC median once more declines considerably, as the economic forecasts became pessimistic due to the starting financial crisis. It seems that the firms again tried to mitigate that impact partly by improving their working capital balances.

Other drivers for a general improvement with regard to the working capital emerge from changes of traditional business circumstances: especially the pharmaceutical sector has historically displayed high profit margins and strong balance sheets, what usually has led to a comparably facile access to new funds (Sage 2009). Furthermore, pharmaceutical companies tended to hold high safety stocks, since stock-outs of essential drugs lead to a bad image and the loss of the customers' trust. In the light of these circumstances, pharmaceutical companies traditionally have operated with comparably high working capital levels and have experienced low pressure for improvements within this area. However, that comfortable state has been jeopardized in recent years by decreasing margins, reduced growth opportunities and less productive outcomes in drug discoveries. These unfavorable developments have forced the pharmaceutical firms to seek for ways to oppose those trends.

The picture is similar for the chemical industry, which is facing on one hand rising costs, mainly due to the increase of the raw material prices (Budde et al., 2006). On the other hand, the chemical sec-tor experiences a permanent price pressure, originating from increased competition, for example through the entrance of new, mostly Asian players. Therefore, the chemical industry is struggling heavily with maintaining the actual level of return on investment (ROI). It is likely that those external pressures have caused the companies to seek for new opportunities to counter these negative trends. Since an optimization of the working capital and its related practices leads to higher access to cash[5], lower costs, lower capital requirements and also to higher sales growth (Losbichler and Rothböck,

5) For example through a better access to credit and through earlier cash inflows.

2008), it is likely that chemical and pharmaceutical firms have tried to take advantage of that leverage in recent years. As mentioned above, the pharmaceutical sector historically operates with high working capital levels. It is therefore very likely that they have tried to enhance their performance through leaner working capital practices.

This conclusion is supported by a study concerning the life sciences industry carried out by the con-sulting firm Ernst & Young (Ernst & Young, 2009), which states that

"within the last year (2008, note from the authors), the number of initiatives launched by com-panies to free up cash has risen sharply."

Last but not least, the further emergence and development of IT systems have enabled companies to improve their data management and enhance their processes and planning accuracies. Due to new and better possibilities arising from the progress in the information technology, the companies are provided with tools for more accurate and resilient planning and controlling outcomes.

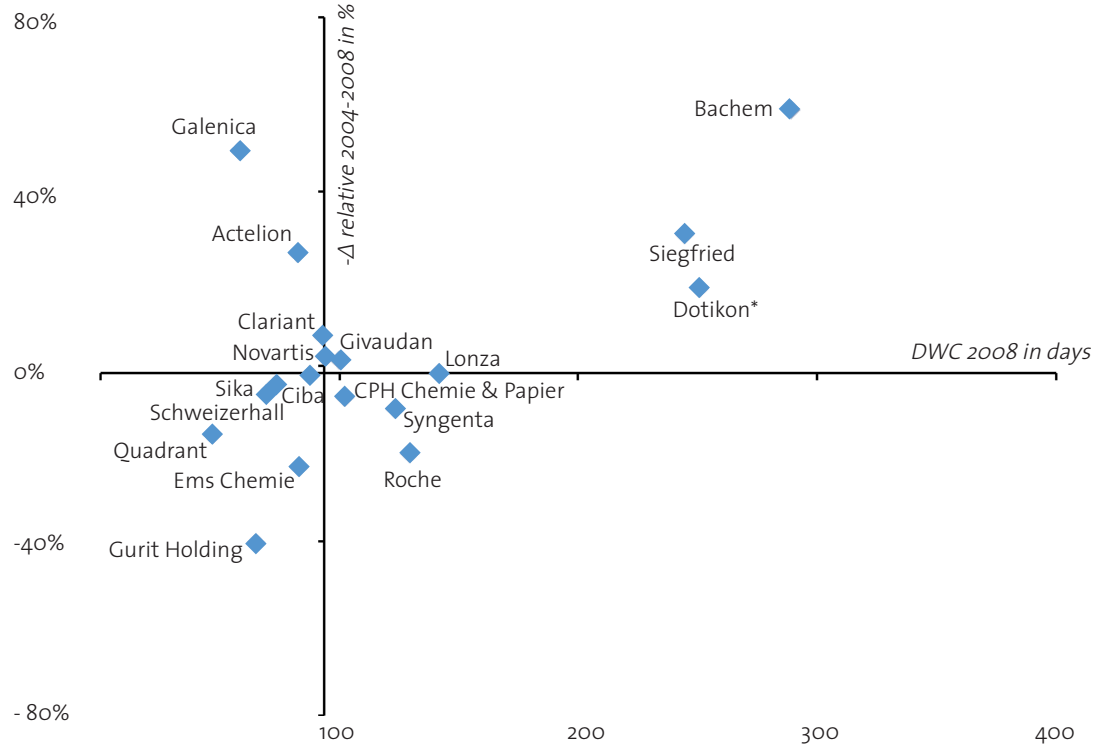
The companies' perspective

The discussion of the results so far has focused on the entire sector. The working capital levels for the individual companies are depicted in Fig. 3. In the DWC portfolio, the Days Working Capital (DWC) ratio in 2008 is compared to the relative change of the DWC since 2004. The interception of the axes is at the DWC median of 2008, at 94 days, and at the median of the changes since 2004, at -1.6%.

Therefore, companies lying in the first quadrant have a high DWC ratio in 2008 and have shown a change less than the industry's median within the last five years. In the opposite quadrant, the third one, firms within that quadrant have a comparably low DWC value in the year 2008, and have still been able to further reduce their accounts receivable relative to sales volume. The second quadrant includes corporations that have a DWC lower than the industry's median in 2008, but which have experienced a change less than the median within the last five years. Finally, companies within the fourth quadrant have a DWC which is higher than the industry's median in 2008, but those firms have reduced their DWC since 2004 to a higher extent than the median value.

It becomes evident that Quadrant, Gurit, Ems Chemie, Schweizerhall and Sika are not only among the companies with the lowest DWC in

Figure 3 DWC Portfolio: Current vs. past performance



Source: Own elaboration, based on publicly available financial statements

* For Dottikon, the change since 2005 is considered, because it went public in 2005

2008, but show also the biggest improvement within the last five years. Bachem, Siegfried and Dottikon, on the other hand, have high working capital levels relative to sales in 2008, and have even seen deterioration compared to 2004. They are thus located at the upper right side of the portfolio.

The amazingly great gap in DWC between the companies in 2008 of 242 days reveals huge differences in working capital management within the industry. The fact that ten out of eighteen companies have been able to reduce their working capital level in the last five years confirms that it is possible to take advantage of the potential which is lying in the accounts receivable, inventories and accounts payable.

Cash potential amounts to CHF 17 billion in 2008

As shown above, the firms within the chemical sector hold different levels of working capital relative to their respective sales volume. By lowering those current assets or increasing the short-term liabilities, companies can reduce their capital and free up cash. The cash potential is calculated by comparing the average net working capital to sales ratio of companies within the first quartile with the actual net working capital to sales ratio of the firms of the upper three quartiles. The companies in the first quartile (in this case Quadrant, Galenica, Gurit, Schweizerhall and Sika) are taken as reference values and hence have no cash potential in this calculation. All other companies are compared to the average of the 25% best performing firms, which amounts to 17.2% for the year 2008. The difference between a firm's NWC to sales ratio and the benchmark taken from the first quartile results in the company's cash potential. It is thus that amount of cash which would be freed up if the company reduced its NWC relative to sales to the average of the first quartile, instead of holding the actual level. For the entire sector, the cash potential amounts to CHF 17 billion in 2008, this is equal to 13.2% of annual sales of the companies in the upper three quartiles.

Performance compared to European and US competitors

Swiss chemical and pharmaceutical companies are operating in a global environment and hence are facing global competition. It is therefore reasonable that they are not only compared to each other, but also to the performance of chemical and pharmaceutical firms based in Europe and the US.

The median values for the different ratios and regions are depicted in Fig. 4. It becomes apparent that the Swiss sector displays higher median values than the European and the US sector for all the ratios and years, except for the DPO. With regard to the DSO median, the gap amounts to approx-imately 20 days to the US median and 10 days to the European median in 2008. The difference be-tween the Swiss DIO median and the US median is 16 days, and 11 days between the Swiss and the European one. The Swiss companies are only performing better than the US ones regarding the DPO median: the Swiss median lies 4 days above the US one, but is still 2 days lower than the European one.

The performances in the single components, especially with regard to the DSO and DIO ratios, lead also to a comparably high Days Working Capital median of 94 days in 2008. It is 19 days higher than the European median, and 21 days higher than the US median.

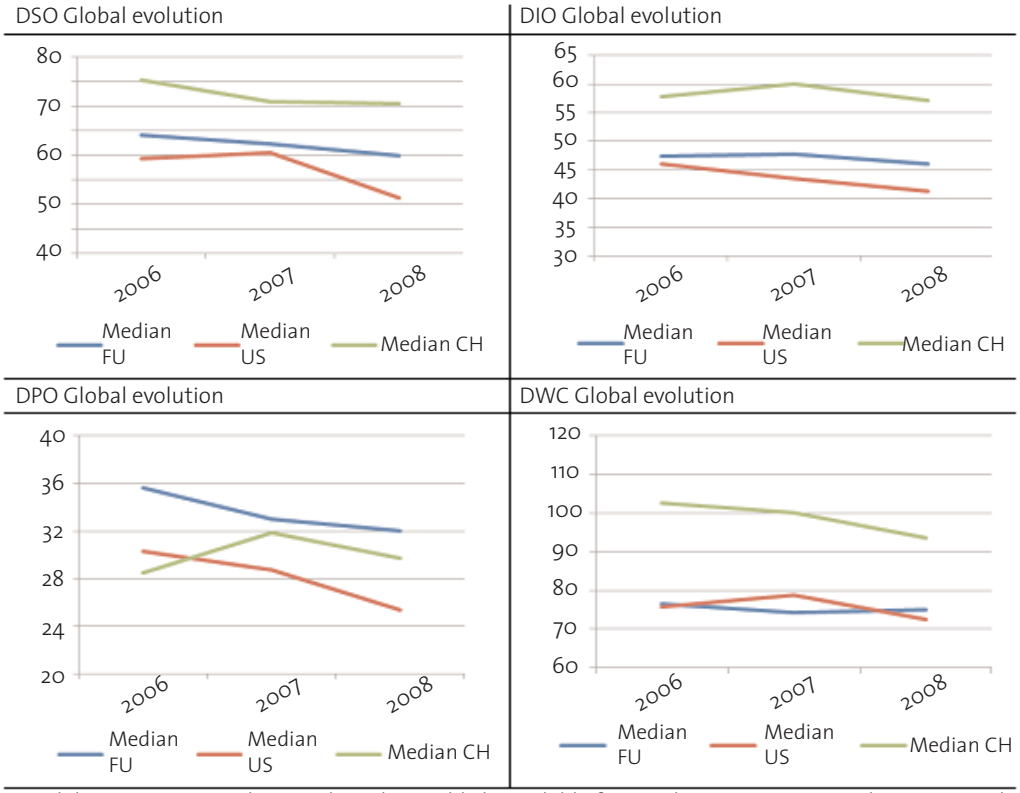
This comparison shows that Swiss based companies are performing on a higher Working Capital level than their European and US competitors on a median basis. In fact, the median Swiss company holds almost one fourth more net working capital relative to the sales volume than its US counterpart, and one fifth more than its European counterpart. Hence, Swiss based companies are keeping considerably higher amounts of tied-up capital that is related to the working capital within their balance sheets. That in turn means that Swiss companies are operating less efficiently than its foreign competitors with regard to their short-term assets and funds and that they could generate a higher shareholder value by adapting the working capital practices of US and European firms (Losbichler and Rothböck, 2008).

Results of the questionnaire

In addition to the quantitative examination of the working capital performance through the analysis of the companies' financial statements, a questionnaire was forwarded to each company (except for Ciba[6]) to obtain some qualitative data. The aggregated results of that survey are intended to give a bigger picture of the relevance of the working capital management for the firms. Nine companies out of seventeen answered the questionnaire.

6) Ciba has been acquired by BASF in 2008, and is fully integrated since April 2009.

Figure 4 Chemical and pharmaceutical industry performance in Europe, the US and Switzerland



Source: Own elaboration, Swiss values are based on publicly available financial statements, US and European values are based on REL/CFO Working Capital Survey 2009

The analysis of the received answers shows that the firms are well aware of the importance and impact of the working capital management on the overall performance. Furthermore, the working capital management is seen as a decisive factor and an important driver of the company's present and future performance. Some of the most distinct answers are presented below.

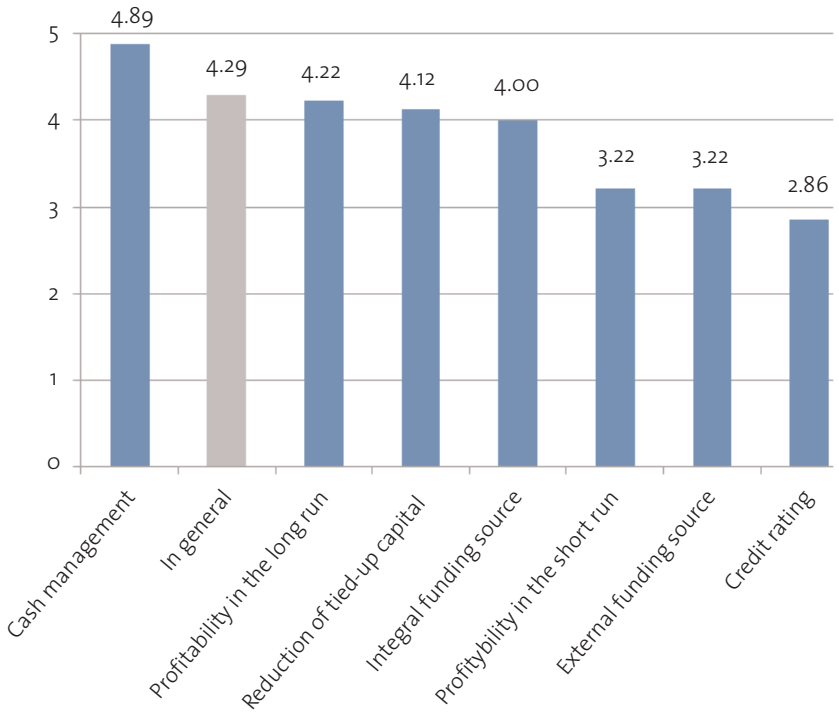
As shown in Fig. 5, the general importance of WCM for the success of the company is considered as relatively high with an average rating of 4.29 on a scale ranging from 1 to 5, with a higher number representing higher importance. The firms see the highest impact on the cash management: eight out of nine companies have stated that the WCM is very important for the cash management. This certainly makes sense, since changes within the working capital directly influence the timing of the cash flows and hence a firm's cash balance.

Another big influence is seen in the profitability in the long run and the reduction of tied-up capital. Those two are closely related to each other, since (all other things being equal) less capital leads to a higher profitability. On the other hand, the firms see a lower impact on the profitability in the short-run, with an average rating of 3.22 out of 5. This might reflect the fact that the actions taken for the improvement of the working capital first cause certain one-time costs and the benefits of the reduction in the WC levels occur later, in the long-run.

Concerning the potential for improvements, the companies were asked to rate the different levels of potential again on a scale from 1 to 5. The higher the number in the rating, the higher is the potential seen by the companies.

With seven companies out of nine stating that they see a potential of 3 and higher, most of the firms detect opportunities for improvements within the working capital management in general. Whereas the companies see the highest potential in accounts receivable and inventories, with an average potential of 4.25, the lowest potential is seen in accounts payable, with an average of 2.875, as depicted in Fig. 6. This is consistent with the rating of the importance of WCM shown in Fig. 5: the firms have stated that WCM plays a more important role as an internal funding source than as an external funding source.

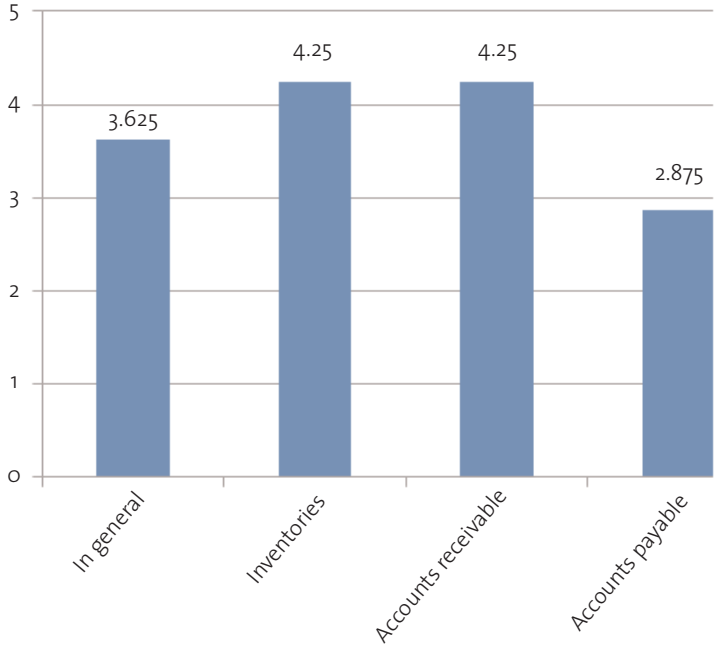
Figure 5 Importance of the WCM concerning different Issues



1= not important at all, 5 = very imortant

Source: own elaboration, based on answers given by companies

Figure 6 Opportunities for improvement



1= not important at all, 5 = very imortant

Source: own elaboration, based on answers given by companies

Managerial implications

The very basic prerequisite of every optimization within the working capital is the management's awareness of the benefits arising from the improvements and the corresponding will to implement the necessary actions and to conduct the appropriate changes (Randall and Farris, 2009). The com-mitment is thus a crucial factor in the implementation of the appropriate activities. Moreover, also the time period of the improvement process highly relies on the willingness of the top management: the higher the commitment and importance given by the top level executives, the earlier reductions in net working capital occur. Besides being a top priority at the upper level, it is essential that the responsible divisions and managers are informed and instructed appropriately. The best strategic decisions do not lead to the desired outcome if they are not implemented on the operational level. Therefore good communication is vital for the achievement of the set targets.

In addition, appropriate actions have to be taken in order to ensure improvements within the ac-counts receivable, inventories and accounts payable. The launch of specific initiatives with quantita-tive as well as qualitative objectives often is a good way to introduce changes in the culture and business processes. Every element provides its own opportunities for an improvement, and requires more or less sophisticated strategies. With regard to the accounts receivable, the negotiation of the payment terms decisively influences the collection period. Moreover, payment delays and failures can be partly avoided by a profound credit analysis of the customer. Other important issues are consistent monitoring and a strict dunning process. There are alternatives to the conventional handling of the receivables, like factoring or credit insurance. However, the benefits of the outsourcing or insurance have to exceed its costs.

An efficient management of the accounts payable is based on a close monitoring of the payment deadlines and potential trade discounts. As long as no cash discount is offered, the cash outflow should be postponed until the due date. There is no benefit of an earlier cash disbursement, and hence the full credit period should be utilized. Cash discounts should be used, if the benefits from the cash receipt are bigger than the opportunity loss of the cash outlay. Similar to the accounts receivable, the payables level depends on the payment terms. Of course, a longer payment period is favored this time, in contrast to the receivables management. The negotiating power can be levered through the building of a central hub, i.e. the centralization of all procurement activities. This is especially important in the chemical and pharmaceutical industry, where business-to-business contacts are predominant with regard to sourcing.

The inventories are the most complex element of the working capital, and often require the greatest effort in order for optimization. Moreover, supply chains and corresponding processes may vary substantially between the different firms. It is therefore difficult to provide general suggestions for all companies. A successful strategy has to be developed with regard to the firm's structure and in collaboration with the responsible operations and site managers, among others. Modern inventory management is supported by advanced IT systems, and different scenarios can be simulated with the aid of sophisticated simulation tools (Adams, 2008). However, the volatility of the oil price, and hence of the raw material and energy prices for the chemical industry, remains a challenge in the future. Lean inventory management thus is likely to gain further importance.

Besides the operational excellence, the inventory level also highly depends on the collaboration within the company, and within the entire supply chain. The various involved divisions within the company have to share their information in order to optimize for instance production schedules or safety stock levels. Decisions and strategies should be developed by integrating the sales, supply chain, production and finance view. A holistic view of operating decisions and its consequences is more likely to succeed in the long term. Interdisciplinary, cross-functional teams can be established to intensify the integration.

In addition, the internal view has to be extended to the whole supply chain (Rafuse, 1996). It is not sufficient to cooperate inside the company. Instead, collaboration throughout the entire supply chain should be aimed, which offers considerable opportunities and competitive advantages. True collaboration includes the exchange of information about current and future demand and supply levels, and the working capital levels are intended to be lowered throughout all members of the chain. The reduction through better data exchange and enhanced communication is more sustainable and promises long-lasting benefits. Collaboration leads to more responsive and resilient supply

chains and that in turn results in lower overall inventory requirements and higher efficiency. Therefore, a paradigm shift is required from an internal optimization of the processes to the optimization of the whole supply chain. In the light of the ongoing consolidation and globalization within the chemical and pharmaceutical industry, the supply chain collaboration becomes an increasingly decisive value driver.

The collaboration does not only offer chances for an inventory optimization. Closer and more intense relationships with customers and suppliers may also enable a company to improve its accounts receivable and payable, and eventually to optimize the whole net working capital.

Last but not least, a consistent and ongoing monitoring and controlling ensures sustainable im-provements, and can be supported and enhanced by a benchmarking analysis and the adaption of best practices.

Summary

The investigation of Swiss chemical and pharmaceutical companies regarding their working capital management has revealed the huge potential which is lying in the management of short term assets and liabilities. Furthermore, the considerable differences between the single firms show that an optimized working capital management may play an important role for a firm's competitiveness. A successful working capital strategy relies on the commitment and awareness of the management and on efficient working capital practices on the operative level. In addition, internal and external collaboration leads to more competitiveness, both for the firm as well as for the whole supply chain. A consistent and ongoing monitoring ensures sustainable improvements, and can be supported and enhanced by a benchmarking analysis and the adaption of best practices.

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