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Innovation Strategies for the Australian Chemical Industry

Garrett Upstill, Alan J. Jones, Tom Spurling, and Greg Simpson

Three-Dimensional Valuation of IP Rights

Bernd Fabry

The Future Belongs to Renewable Resources

Stefan Nordhoff

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Letter from the Editor

Changes in the Chemical Industry

Fundamentally, chemistry is the study of matter and change. In the course of time, many different subdisciplines have emerged, following very diverse research approaches: e.g. organic, inorganic, physical, analytical or biochemistry. All of these generated great scientific discoveries, paving the way for the rise of the chemical industry – today one of the largest and most diversified industries in the world.

However, which of these subdisciplines has the capability of studying the changes in the chemical industry itself? Can any of them adequately address questions concerning, for example, the exploitation of the emerging research fields of nano- or biotechnology, or the strategic importance of renewable resources? We believe this challenge requires new research strategies – open-minded and innovative – that bridge interdisciplinary gaps and illuminate complex problems from various perspectives. With the *Journal of Business Chemistry*, we try to offer an international discussion forum for researchers and practitioners from different disciplines, aiming at a deeper understanding of the changes occurring in the chemical industry. In this issue, we would like to highlight three topics increasingly being discussed in academia and practice.

The first topic is science communication between experts and non-experts. Regrettably often neglected by the chemical industry in the past, the example of agricultural biotechnology in Europe made clear to everybody how a lack of information can cause consumers to boycott new technologies. This issue's commentary deals with this matter against the background of nanotechnology and points out possibilities for efficient communication between experts and non-experts.

Intellectual Property (IP) rights and their growing importance in the chemical industry is the second topic. The value of more and more companies (major players as well as start-ups) is largely based on their treasure of patents and copyrights. To obtain a realistic picture of a company's value it is therefore indispensable to value its IP rights. One of this issue's research articles addresses this point and proposes a three-dimensional valuation of IP rights.

The third, and probably most far-reaching topic, is the future development of the use of renewable resources in the chemical industry. In the face of steadily rising oil prices and the inescapable depletion of fossil resources, chemical companies – sooner or later – will have to source their raw materials from renewable resources such as corn or sugar cane. This issue's practitioner's article underscores this development and analyzes the future possibilities for natural raw materials in the chemical industry.

We would like to thank all authors and reviewers for their contribution to this bouquet of highly interesting themes. Now enjoy reading this third issue of the *Journal of Business Chemistry* in 2006. If you have any comments or suggestions, please send us an e-mail at contact@businesschemistry.org.

Benjamin Niedergassel

Commentary

Dialogue on Nanotech: The South Carolina Citizens' School of Nanotechnology

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Abstract: Theory and experience emphasize that science communications between experts and nonexperts should be dialogue, not monologue. This principle guides a nanotechnology outreach program at the University of South Carolina which enables the participants to express their values and concerns to experts, and to question them. It is intended that the knowledge and confidence generated by this program will enhance the participants' ability to have active and constructive roles in nanotech policy.

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Introduction

In December 2003, the U.S. National Science Foundation convened a workshop on societal implications of nanotechnology. Three troubling themes arose: (1) that public awareness of nanotechnology was almost nonexistent; (2) that polarizing visions of nanotech were well established, and would dominate the ideological landscape in lieu of balanced or centrist visions; and, (3) that communications regarding nanotechnology must not be one-way messages from experts to nonexperts, but should be dialogues in which nonexperts can question the experts and express their values and concerns.

A group of researchers at the University of South Carolina has been concerned about technological determinism, i.e., that nanotechnology might change our lives without any consideration for the values or concerns of consumers, nonexperts, or other stakeholders. The themes of the NSF workshop inspired members of this group to create a dialogue-based outreach program, the South Carolina Citizens' School of Nanotechnology (SCCSN).

This program should be understood in light of the history of the role of nonexperts in science policy. In the American experience, John Dewey argued that when citizens think scientifically, democracy and science benefit each other [1]. But this requires a well-informed citizenry. Jon D. Miller has measured scientific literacy across three decades, and his results show that it is consistently very low [2, 3]. There are some exceptions and improvements, but we conclude that it is unlikely that large proportions of Americans will be well informed about nanotechnology [4, 5, 6, 7, 8, 9].

At the same time, four observations point to constructive roles for nonexperts in science policy. First, stakeholder democracy indicates that for any given issue, some people will decide to become active [10, 11, 12], even if most are uninterested and inert. Secondly, studies show that nonexperts can acquire and comprehend scientific knowledge when they have to in order to participate in science policy [13, 14].

Third, informal science education is especially effective because it is self-motivated [15]. Miller has noted that this is one of the most powerful sources of scientific literacy, and it is easier to experiment with than other variables [3]. Experiments with informal science education include science cafés, mini medical schools, and consensus conferences [16, 17, 18, 19].

Finally, those observations culminate in participatory democracy, i.e., cases in which nonexperts have active and constructive roles in science policy. Some examples are: local cases of public health or environmental threats; patients' families organizing to support medical research; AIDS activists improving biomedical knowledge in epidemiology and clinical trials; and laypersons steering the board that created regulations for research on recombinant DNA in Cambridge, Massachusetts.

Nanoliteracy & the SCCSN

The University of South Carolina group has a vision we call "nanoliteracy," a condition in which:

- People who are interested in nanotechnology are reasonably informed about it, are aware of a spectrum of views, and can learn more on their own; and,
- Stakeholders are confident they can participate in shaping nanotech policy, even if they do not have expert scientific credentials; and,
- Societal questions are integrated into discussions about technical change, so the technology is not isolated from society.

This raises the question of implications and interactions. Government agencies speak of the societal implications of a new technology, but this usually means that the technology arrives, it changes society, and the change is understood after the fact. We prefer not to passively accept this. Instead, nanoliteracy means that one can understand nanotech now, before it causes major disruptions, so that people can advocate beneficial changes. Thus we speak of societal interactions with nanotech, meaning that nanoliterate stakeholders make decisions before technological change becomes a fait accompli [20].

The SCCSN is our premier program for nurturing nanoliteracy [21, 22, 23]. Our model has these elements:

- A package of readable articles gives the participants background and confidence to question the speakers.
- The speakers are faculty experts who are adept and comfortable in speaking with nonexperts.
- There are numerous opportunities for the participants to pose questions and comments.
- To ensure a friendly atmosphere for questions and discussions, enrollment is limited to fifty or less.
- The program is open to revisions and improvements as suggested by the participants.

For example, during the first round (Spring 2004), the participants heard much about the scanning tunneling microscope, the atomic force microscope, and electron microscopes. They were extremely curious to see these machines in operation, and so suggested adding a lab tour. This was done in the second round and thereafter: the group visited the Electron Microscopy Lab and a Chemistry lab with an STM. They saw the imaging of nanoscale materials and surfaces (ranging from 30 to 0.27 nm) in real time, and the faculty explained the instruments. For nonscientists, this was a rare and exciting insight into the workings of nanotechnology.

Currently, each round consists of six presentations, once a week, supported by a package of readable articles, plus a lab tour, and a roundtable discussion at the final session. The SCCSN benefits from a structure of topics and readings in which societal issues are as prominent as the scientific information [11, 20, 24], but its special strength is the ethos of dialogue that shifts the focus from the speakers to the participants. This is expressed six ways:

- Participants pose questions and comments during the presentations;
- A thirty-minute discussion period after each presentation generates more dialogue;
- Some participants talk with the speakers face-to-face after the formal program concludes;
- Some participants later join the speaker and the organizer at a coffee house;
- Each round concludes with a ninety-minute roundtable discussion with all the speakers, with a participant serving as the facilitator; and
- Some participants have on-going contact with the speakers, usually by email.

We give two examples of creating dialogue. In Fall 2004, Robert Best spoke on nanomedicine. He had a well-developed powerpoint presentation, but on the evening of 20 October we could not get into the computer because C. Toumey could not find the password. So Best delayed his formal presentation, and he began by soliciting questions from the participants. This had an excellent effect: it was clear that the evening would be driven by their concerns, not his conclusions. His talk still had a structure which moved from topic to topic, but it was flexible and participant-friendly, resulting in ideal dialogue between participants and expert.

In a second example, the initial presentation of the fourth round (Fall 2005) was Davis Baird's fifty-minute historical introduction to nanotech, during which participants asked 24 questions. Many professors would feel that this was an annoying number of interruptions, but D. Baird and C. Toumey saw it as an excellent indication that the participants knew that they too were principals in this outreach program. During the same round, participants suggested adding an eighth session, the roundtable discussion. This was another successful exercise in dialogue, and has been incorporated into subsequent rounds.

Compared to other forms of informal science education, the SCCSN is more intimate than a mini medical school, more formal than a science café, and, with its background readings, it provides more depth of content than the other two forms. It can also co-exist with those other formats, and in fact a group of SCCSN participants organized a science café for Columbia, South Carolina, in July 2006.

Metrics and other indicators

Preliminary metrics from baseline and end-point tests of nano-knowledge and attitudes show that participants' knowledge changes markedly. Examples are:

	Baseline	Endpoint
Recognizing the importance of the STM for nanotechnology	32%	100%
Recognizing that the fullerene molecule is made of carbon	53%	94.4%

Even more important, however, are changes in participants' confidence. They report becoming more confident about: (1) explaining their positions on nanotech; (2) understanding a newspaper article on nanotech, and (3) speaking publicly at a hypothetical community meeting on nanotech policy.

A second line of investigation consisted of a record of participants' questions and comments, from which themes were identified by J. Ryan Reynolds during SCCSN.4 (Fall 2005). There were 46 participants, and the average attendance was 28 participants. Three themes emerged from that work:

Gender and Nano-Curiosity : was there a relation between gender and the questions asked by participants? The proportion of males to females was approximately 3:1. An average 15.4 questions per session were asked by males, compared to only 2.2 from females. The questions were separated into technical (n = 36, e.g., "Could assemblers be reprogrammed to disassemble?") and social (n = 52, e.g., "I'm concerned that nanotechnology will benefit only a select group of people."). Women asked one technical question and 11 social, while men asked 35 technical and 41 social. This is not a simple bifurcation of males asking about science and females asking about social issues: there was a strong preference for social questions by female participants, yet the male participants exhibited a balance of the two concerns.

Growing Sophistication : there were some very sophisticated questions at all sessions, but the proportion of simpler questions diminished across eight sessions. From the first session: "are all atoms the same size?" From the last session: "If we could build a particle accelerator on the nanoscale, it seems we could build a very good one due to increased surface area." This may be partly because the topic of the first session was an introduction to nanotechnology, while the topics of the later sessions were more sophisticated. If so, the participants' questions and comments kept pace with the development of the session topics.

Prominence of Health and Medicine : the session on nanomedicine had the largest number of questions (n = 25), and additional questions on health and medicine arose at other sessions. This was clearly the most prominent theme of all. This corroborates survey research which shows that the most important benefit of nanotech is expected to be medical applications [4, 5].

Our third set of indicators comes from A. Aggelopoulou's debriefing of faculty who had spoken in the first five rounds. Eleven of the thirteen speakers were debriefed, including two who had spoken in all five rounds, and three who had spoken in four of the five. This group comprised six chemists, two philosophers, and one each from English, Art and Genetics.

Had their experience with the SCCSN changed the direction of their research? Only one answered affirmatively: a philosopher said he was more concerned than before about the participants' interest in near-future commercial products. The sense of this is that products like cosmetics and nano pants seem trivial, but this is how consumers will encounter nanotech in the near future. In addition, he noted the participants' interest in Drexlerian nanobots. Although he considered them unrealistic, it impressed him that nanobots were prominent in the participants' views.

A chemist had an interesting reaction to that question: although the SCCSN had not changed the direction of her research, "the participants' insistence in knowing how the various aspects of my research are important and relevant has forced me to face the same questions."

Almost all of the speakers said they had changed the ways they present their research to make it more accessible to nonexperts. Most were surprised and impressed that the participants were well informed, reasonable and articulate. They appreciated that the participants were enthusiastic about nanotech, but were concerned about their high expectations, and were bothered by the participants' interest in nanobots and grey goo.

Finally, they noted the participants' strong curiosity about medical applications.

The future of the SCCSN

The experience of executing five rounds gives us an opportunity to use the SCCSN as a platform for experimenting with informal science education. We can try new ideas within a reliable program.

The round for Fall 2006 (SCCSN.6) includes an experiment in generating policy recommendations. P. Hamlett and others have emphasized that consensus conferences and citizens' juries generate better policy recommendations than focus groups or survey polling because the former give people plenty of time and opportunity to investigate and discuss a topic [16, 25]. The latter are quick snapshots of public opinion, with little or no learning or deliberation. Considering that each round of the SCCSN is an eight-week process of learning and dialogue, it is worth asking whether this process can generate policy recommendations.

For SCCSN.6, the participants are asked, when they enroll, to react in writing to a pair of policy questions: (1) how to balance concerns about privacy with changes in the quality of biomedical information that come from nanomedicine; and (2) whether appropriations to the USC NanoCenter from the state government should specify research directions, or defer to the scientists in the NanoCenter.

At the third and eighth sessions, the participants will face the same questions again. Then a group of participants will synthesize their reactions into a set of policy recommendations, possibly including a minority report.

This way, the participants will have multiple opportunities to deliberate, plus three opportunities to put their views in writing. While there are differences between this process and a consensus conference, we anticipate that it will generate well-informed recommendations from stakeholders that are approximately as credible as those generated from a consensus conference.

Meanwhile, the staff of the SCCSN recognizes three additional areas to develop. We hope to increase the ethnic diversity of the participants so that more nonwhite people will participate. Next, we are curious to know whether science museums can build nanoliteracy on the SCCSN model. Finally, we feel intuitively that the SCCSN model could serve other scientific topics besides nanotech, and we would like to see this tested. Currently we are seeking support to explore these areas.

Conclusions

We emphasize that the South Carolina Citizens' School of Nanotechnology is not a one-way transmission of information from experts to nonexperts. On the contrary, it is a dialogue in which scientific knowledge intersects with laypersons' values. Both are intensely important. It is our hope that the SCCSN will lead to participants making active and constructive contributions to nanotech policy that are infused with both good science and articulate expressions of concern about the future of nanotechnology.

Acknowledgments

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Research Paper

Innovation Strategies for the Australian Chemical Industry

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Abstract: The Australian chemical industry is facing a testing period as it adjusts to the challenges of the new global era. This paper briefly traces the evolution of the industry through an extended period behind protective tariff barriers to the situation today, as it confronts the new competitive environment. While the industry is adjusting as new companies emerge and specialist export-oriented production increases, the current situation continues as "work in progress". We argue that its future success will depend on its ability to innovate and to renew itself. We draw some generic lessons from a review of successful innovation in the Australian chemical industry and identify four key strategies for companies namely: (1) working within existing global value chains, (2) engaging with other globally focused industries, (3) developing an integrated packaging concept for their products and services, and (4) leveraging the knowledge of others.

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Introduction

The central role of the chemical industry in the economic and social fabric of most advanced economies has been demonstrated over the past 150 years. Over that time the industry has been continuously transformed by the introduction of product and process innovations largely driven by research and development conducted by corporations, universities and national laboratories. The industry produces over 70,000 different chemical substances valued at over USD 1.5 trillion per annum [1]. In more recent times the industry has faced some serious problems with the evolution of global markets, the growth in regulatory controls, the slowing down of innovation as exhibited in diminishing returns to R&D, and skills shortages [2].

Arora et al. have highlighted the role of science in the productivity and growth of the chemical industry in Europe, the United States and Japan [3], the changes in the industry brought about by licensing of patent protected technology [4], the changing division of labour and emerging markets for technology in the chemical industry [5]. Arora et al. described the massive restructuring that took place in the US chemical industry in the 1980's (well in advance of Europe or Japan) and which contributed to improved results in many US chemical firms. In particular, these authors noted the division of "innovative" labour and the development of wide networks of collaboration prevalent in the new and emerging areas of the chemical industry in contrast to the activities of the large-scale basic 'commodities-type' chemical industry. Both of these factors are important as the Australian chemical industry makes readjustments to market deregulation. In addition to the work of Arora et al., other literature has also addressed the importance of large scale production [6], and the increasing rise of licensing activity [7]. Very recently, Swift [8] reviewed the near-term business environment in which the world industry will operate and the prospects and challenges to be faced in 2006 and 2007.

In addition, there have been a number of reports addressing some of the problems facing the industry at the level of national concern:

- In the European Union [9, 10] the frequency for innovative opportunities has been a major concern along with the issue of the number of newly banned chemicals. Harries-Rees [11] has suggested that there has been a shift towards short- and medium-term customer and market driven incremental changes in products and processes in the European industry, with higher risk longer-term activities have been handled in a variety of individualistic ways in different companies – motivated by "getting the balance right" between the short/medium- and long-term activities. In addition, international collaboration at the research level, and the movement of people and ideas within the industry, has occurred [11].
- In the USA two reviews [12, 13], and the establishment of the industry-led Chemistry Industry Vision 2020 [14] with a strong emphasis on energy efficiency and protection of the environment and more recently on environmental and health impacts of nano-materials [15].
- In the UK [16], Japan [17], and Denmark [18], where energy savings emerge as a principle issue.

Whatever the commentary, the fact is that each company working in the chemical industry must chart its own innovation strategy in such a way that exploits its key strengths and the opportunities that are available to it. This may take a variety of forms. Innovation may be technological – in the form of new products, or processes - or non-technological – e. g., in the form of new services or organisational arrangements as described by Tidd et al. [19]. Moreover, increasingly it is likely to involve others outside the company for ways to develop and exploit ideas, as Chesborough convincingly argues [20]. Nonetheless, the envelope of strategies that are available for countries will differ according to different national innovation systems, including consideration of the nations' resource endowments, the company base and the links with international companies, and the particular regulatory settings in which they function.

What is the Chemical Industry?

We follow a structure of the chemical industry as defined by the international Standard Industry Classification (SIC) codes, which are used for data collection on the industry. Although the code systems used from nation to nation are marginally different, in general, the chemical industry embraces the manufacture of basic chemicals (including chemicals derived from coal and/or oil), other chemical products (including medicinal and pharmaceutical products), rubber and plastic (or polymer) products. In most cases the industry includes all products derived from petroleum refining [21]. We have also included consideration of biotechnology since much of the activity in this area in Australia is directed towards R&D on pharmaceuticals.

Impact of Change on the Australian Chemical Industry

The Australian chemical industry has also faced testing times in confronting the challenges posed by globalisation and the changing patterns of production and trade. Even though the Australian industry is enmeshed with the global chemical industry, its companies face a different set of challenges and opportunities. In particular it needs to rethink its prospects, and the role of innovation. For many years the industry was protected from external competition by high tariff barriers and restrictions to trade. With the liberalisation of world markets and the substantial lowering of tariffs, the future success of the industry in Australia will depend on its capacity to change through innovation, to introduce competitive new and innovative products, processes and services, and meet the demands of both existing and new markets.

Although the Australian industry is not large on a world scale, it plays an important role in the national economy and is integrated with the global industry through the presence of multinational companies and the trade in chemicals. The Australian industry is important in several niche areas, for example, explosives, pharmaceuticals and agricultural chemicals. It has also benefited from a strong publicly funded research system. At the same time the industry continues to undergo the pains of adjustment as sectors hitherto protected by tariff barriers face new tough competition from overseas. The industry will need to continue to change in the years ahead.

To this end the Australian government in consultation with industry recently released two reports (Chemical and Plastics Action Agenda [22] and Pharmaceuticals Industry Action Agenda [23]. These reports set out industry goals and suggested actions in areas such as regulatory reform, investment and reinvestment in growth, in an attempt to ensure that a highly skilled workforce is available [22]; that Australia is positioned as a global pharmaceuticals hub; that a globally competitive operating environment is created; and that the ability to commercialise research by investing in skills, and by fostering a positive culture, image and profile for growth is strengthened [23].

The Action Agendas reflect current industry policy thinking in Australia, namely that government can contribute best by removing regulatory impediments, promoting the flow of information and skills, and ensuring that the public infrastructure permits competitive companies to emerge. Since the early 1980s there has been a distinct shift in government, away from programs of selective support for industry, and little to no sympathy for "picking winners".

While the Action Agendas have paid attention to the importance of international competitiveness in the industry they fall short in exploring in detail any of the strategies that may be available to the industry at large to innovate, and thus achieve a more competitive position. This paper addresses these issues in more detail, but first reviews the external and internal setting of the Australian chemicals industry and the factors that have shaped its development.

Methodology

We have adopted an inductive, comparative case study approach to theory development [24]. This permitted new factors to be examined as they emerged while also allowing patterns to be compared and contrasted across the cases. The case studies involved personal interviews by at least one of the researchers with senior personnel in each company, following a prescribed systematic format, which specifically addressed the circumstances relating to the development and implementation of their innovation(s), but also permitted some flexibility in the discussions. In total we have conducted case studies on over 25 companies working in the chemicals sector. The choice of the case study approach was also motivated by our interest in developing a consistent framework to embrace the innovation activities of these companies over time, and to monitor the achievements for a wide range of emerging Australian science and engineering based companies working in the chemical industry [25]. Several of the case studies have also formed the basis for a series of detailed industry profiles to inform specialists working in the chemical/biotechnology sector [26]. It is also important to note that many of the newer companies reported in this paper may be characterised as having advanced technology products developed from the R&D base, and supported by strong intellectual property protection.

The historical setting for the Australian chemical industry as a whole has been well documented by Kolm [27].

In addition to the case study approach we have analysed some of the dynamics of change within the industry sector by examining the National Accounts (the industry input-output statistics) available for Australia and a number of other countries (the latter are not discussed) over the period of fifteen years from 1983-84 to 1998-99 [28]. While the present analysis is preliminary, it serves to amplify the enormous changes that have occurred in the chemical industry sector, especially over the period involving the sector's radical transformation through opening up the economy to international competition and globalisation.

Strategic Setting

Evolution of the Chemical Industry in Australia

The chemical industry in Australia has its origins in the nineteenth century. Chemical manufacturing was initially directed towards meeting the needs of new colonies, and to support its resource-based industries [27]. Fertilisers were needed for Australia's nutrient-poor farmland, explosives for its mines, and processing chemicals to treat its mineral ores. The high cost of international freight meant that it was more economic to manufacture chemicals locally and a small but growing domestic manufacturing base emerged.

The focus on local markets continued well into the twentieth century, supported by the high tariff walls and licensing arrangements that applied to the manufacturing sector. This situation prevailed after the Second World War when government policies supported growing "infant industries". From the 1950s a number of multinational companies entered Australia's manufacturing sector, and expanded the ranks of the Australian chemical industry, which consisted of a large number of small and medium sized companies and just a few sizeable companies such as the diversified chemical producer ICI Australia (now Orica), Faulding Pharmaceuticals, which is now part of the Mayne Group and Nicholas (Aspirin), which is now owned by Bayer.

While manufacturing tariff protection provided a cushion for the Australian chemical industry and secured local markets, it retarded innovation, expansion and export seeking growth. There were also no government incentives for innovation-based exporting companies. A leading example is the integrated petrochemical complex established in Victoria in 1961 by a consortium of seven companies, Mobil, Exxon, Dow Chemicals, Union Carbide, BFGoodrich, BASF and Hoechst. It was built to process the oil findings from Bass Strait and produce synthetic resins and chemicals. While the plant operated efficiently in the tariff protected environment it remained small scale by world standards. The failure to expand the plant to world scale and compete internationally meant it became uneconomic when tariffs were eventually reduced.

In the 1980s the Australian government commenced a series of reforms to deregulate the economy and reduce tariffs. The 1986 recommendations of the Industries Assistance Commission were adopted and tariff barriers for the chemical industry progressively decreased from levels as high as 45 % to between zero and 5 % by 1996. The tariff reductions were inevitably accompanied by increased imports. Further, the industry had to deal with the problem of aging assets and sub-scale plants and find ways to access international markets. Today the industry continues to restructure to meet the demands of global competition.

Some companies continue to be in the throes of adjustment, while others have made the transition with some success. On the positive side, a number of new, “born-global” companies have been formed across parts of the industry [29].

The Australian Chemical Industry Today

The chemical industry accounts for about 12 % of total manufacturing in Australia, with a turnover of about AUD 28 billion (1999-2000) and employs over 91,000 people [23]. In 1999-2000, AUD 4.5 billion worth of chemical products were exported and AUD 15.1 billion of chemical products imported – a net deficit of over AUD 10 billion. Australia accounts for only about 1 % of world chemical production and is clearly a significant net importer of chemicals. There are some 3,800 enterprises operating across the full spectrum of the chemical industry. More than 80 % of these are small and medium-sized businesses, each employing less than 200 people. The Australian industry is also geographically dispersed, with activity spread across the States of Victoria (38 %), New South Wales (34 %), Queensland (12 %), South Australia (7 %), Western Australia (7 %), and Tasmania (2 %).

The industry is extensively linked to the global chemical industry as well as most of the major ‘big pharma’ pharmaceutical houses., through international trade and the operations of several multinational companies such as DuPont, Dow Chemical, Huntsman, Pfizer, Exxon Chemicals, Merck, Pharmacia, Bristol Myers-Squibb, Eli Lilly, Wyeth, Schering Plough, Bayer, BASF, Sanofi-Aventis, Degussa, and Boehringer-Ingelheim**.** There are just a few large local companies such as CSL, Orica, Nufarm, and Incitec.

The amount spent on research and development by the chemical industry in Australia is not large by international standards AUD 584 million in 2003-04 [30]. Of the top 50 R&D performing business spenders in 2002-03, 14 were in the chemicals sector. These companies spent over AUD 275 million on R&D in 2002-2003, with the biomedical/chemical company CSL Ltd being the leading performer spending more than AUD 90 million per annum [31]. In the related biotechnology sector the total R&D expenditure was AUD 378 million. Most of the multinational companies conduct R&D in Australia – indeed pharmaceutical multinationals rank in the top 50 business spenders on R&D, but the expenditures of the multinational companies are just a small fraction of their global budgets.

An offsetting factor is the expenditure on R&D by the public sector through universities, and research institutions such as CSIRO and State agencies. Australia has high public spending on R&D across all the manufacturing sectors. The strong research base is reflected in Australia’s position of 15^{th} in an international ranking of chemical publications with 15,682 papers published in the decade to August 2004 [32]. In addition, the medical and health related research provides a platform of support for the local chemical industry. In 2002-2003 Australia public funded expenditure on the chemical, biological and medical and health sciences was AUD 3.15 billion.

To illustrate how the chemical industry in Australia has evolved over the past two decades we compare data from the Australian National Accounts for 1983-84 with that of data for 1998-99, namely a gap of some 15 years, and one embracing the critical changes in micro-economic reforms. Australian National Accounts’, data at the 4-digit level provides detailed information on the inputs to a selected industry sector and traces these inputs to outputs across all sectors in the economy [28]. In order to provide a simplified illustration of the transformation of the chemical sector over the 15 year gap we have plotted the common inputs for each of the chosen years against the outputs across all important, but aggregated, sectors of the economy, as shown in Figure 1 for 1983-84 and Figure 2 for 1998-99.

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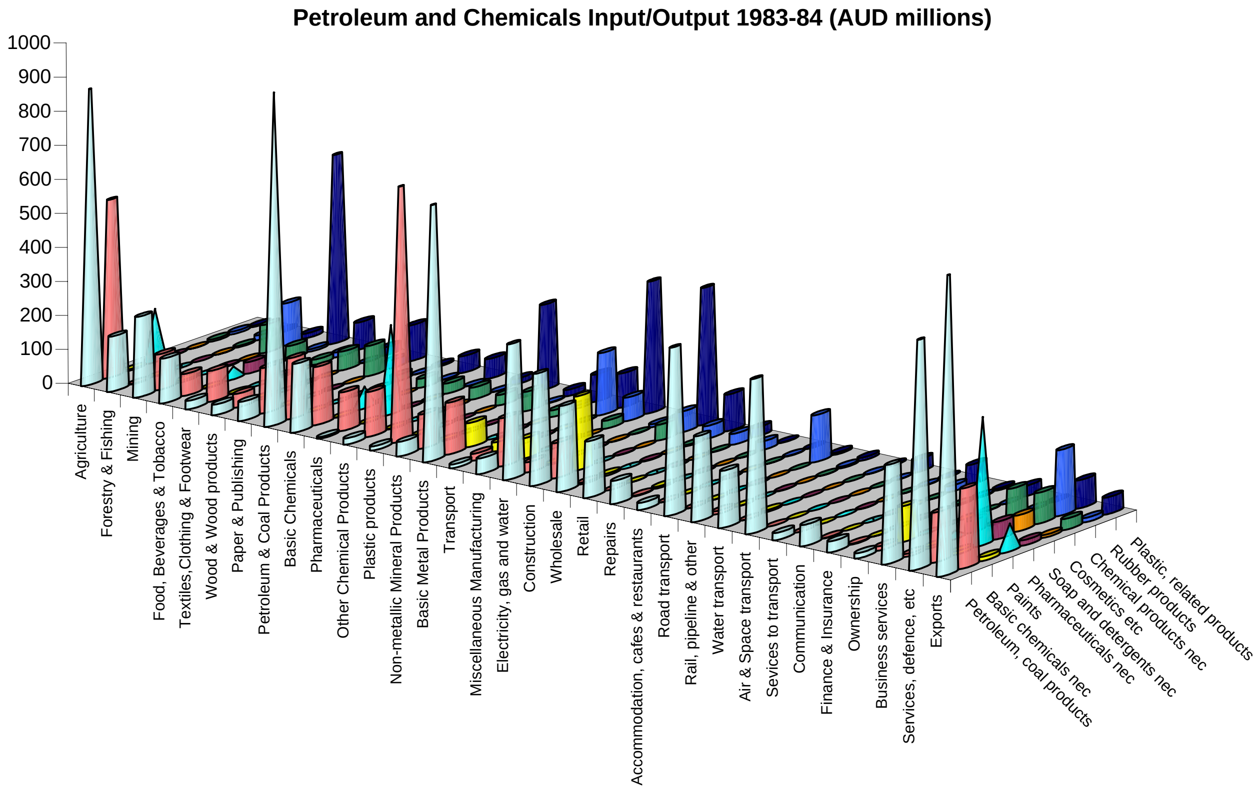

Figure 1: Input/Output Data for the Chemicals Sector A - 1983-84

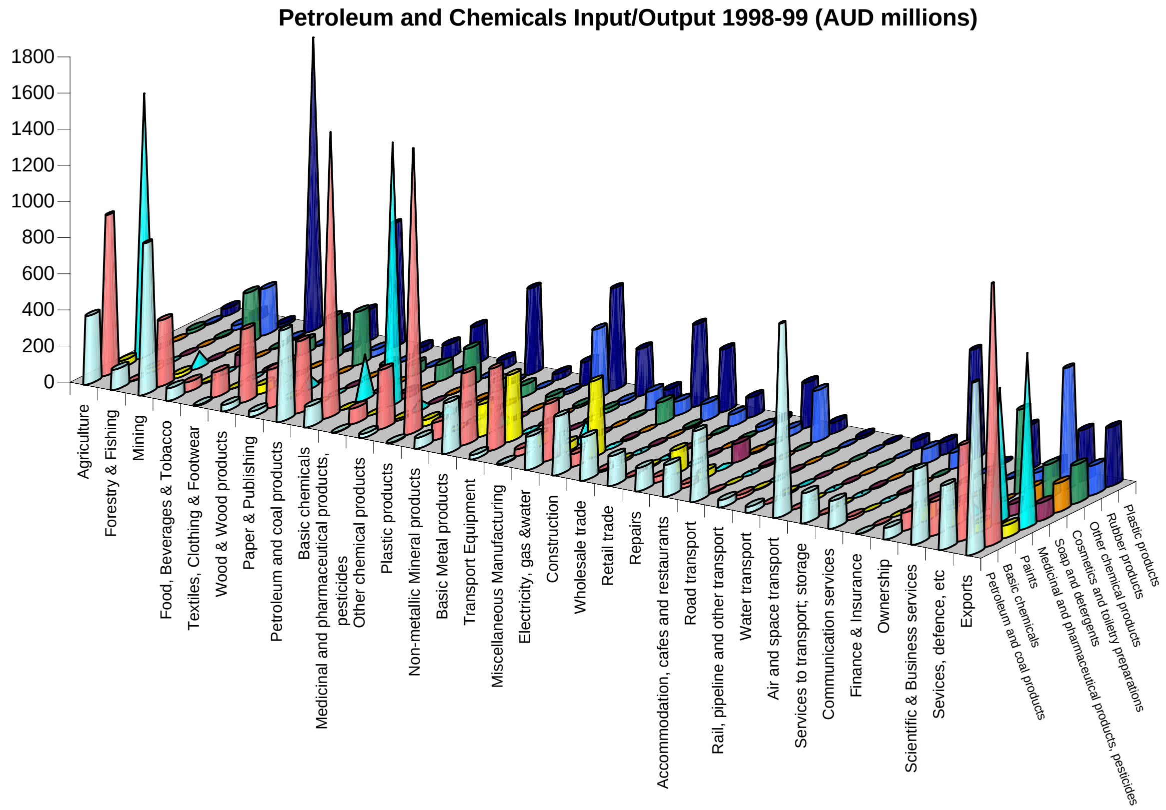

Figure 2: Input/Output Data for the Chemicals Sector B – 1998-99

The stark changes in the contributions of the chemicals sector to other sectors of the Australian economy are shown by the changes in the magnitude of the peaks in these plotted matrices. For example, by 1998-99 the medical and pharmaceuticals (human and animal) element of the sector exhibited a substantial increase for exports ~AUD 75 to ~ AUD 956 million and in uses in agriculture ~ AUD 152 to ~ AUD 1,447 million, and doubled in magnitude in the provision of medical services (AUD 365 to AUD 734 million). In contrast, the use of chemical products in agriculture decreased substantially from AUD 863 million in 1983-84 to only AUD 376 million in 1998-99, as did the application of chemical products within the sector itself, from AUD 967 million to AUD 500 million. The applications of polymers (plastics) in the food, beverages and tobacco sector and of rubber in the mining sector rose from AUD 554 million to over AUD 1,610 million, and from AUD 124 million to AUD 255 million, respectively. Exports from Australia of petroleum and coal products rose for each element in the sector, but most particularly for pharmaceuticals, and for basic chemicals from AUD 229 million to AUD 1,449 million. In this paper our intent in using the national accounts data in this way is to stress that the chemicals sector has transformed to one much more strongly driven by meeting consumer and market demands over the 1980s to late 1990s.

Innovation and Industry Competitiveness

Innovation

There have been some notable successes over recent years and the Australian chemical industry appears to have lifted its innovation profile since deregulation (in this context success is defined by the commercial exploitation of ideas or continued operations with an increasing export profile). The Australian industry has long had a relatively strong record in support of domestic customers in the non-protected sectors of agriculture and minerals. In the case of minerals this extends to mining explosives and corresponding services to the mining sector, advances in minerals exploration [33], flotation techniques in metal ore processing [27], and geochemical techniques in gold exploration [34]. In agriculture it includes plant and veterinary chemical developments [35]. And there is a long-standing tradition in scientific instrumentation, which stems from the invention of the atomic absorption spectrophotometer and other instruments which have now reached high export penetration levels [26]. The industry continues to have access to a broad ranging public sector research base in chemistry – in the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Defence Science and Technology Organisation (DSTO), Australian Nuclear Science and Technology Organisation (ANSTO), the universities, and the Cooperative Research Centres (CRCs). Publicly funded biomedical public research institutions, the original home to nine to ten Nobel Prize winners, has provided the springboard for the development of the medical and health products industry (including pharmaceuticals). More recent examples of innovative outcomes in the Australian chemical industry are provided in more detail in Section 5.

In addition, an analysis of patenting activity in the USA for a range of OECD countries, including Australia, independently demonstrates that over the period 1980 – 2001 Australia concentrated on slow changing technologies (having high technology cycle times, but with a strong focus on the scientific knowledge base, i.e., strong linkages between patents and scientific publications). This analysis is neatly summarised in Figure 3 [36]. Note that TCT was calculated on the basis of the average age of the patents cited, and SL on the number of scientific publications cited in the patent.

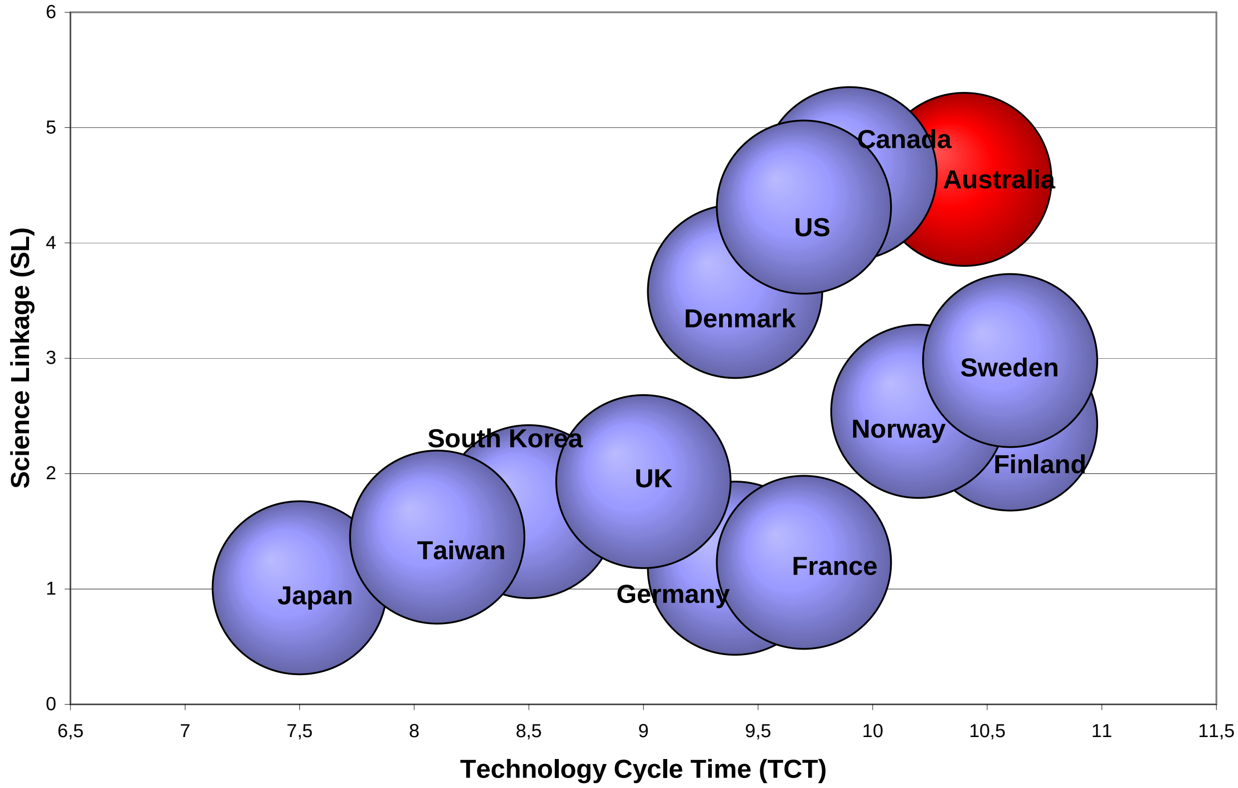

Figure 3: Patent outcomes for a variety of countries showing the link between science linkages and technology cycle times [36].

International Competitiveness

Let us consider the return on investment in innovation across the chemical industry. Using R&D intensity (R&D expenditure/sales) as a proxy, Simpson et al. [37] have shown that the Australian chemical industry may be considered as subdivided into three segments or "tiers". Further, the growth prospects in each segment of the industry can also be deduced.

- **Segment 1:** The low R&D-intensity segment of the industry includes companies engaged in the production of high volume, low-value added products such as mineral-based inorganic chemicals, petrochemicals, and bulk polymers. This industry segment has diminished in importance in Australia as petrochemical and polymer production has moved towards a few world-scale production facilities – none of which are located in Australia, this in spite of the sustained process innovation that has occurred over the years in the design and application of catalysts to improve process efficiency, and to which Australian scientists have made significant contributions. Moreover, this is a relatively mature segment of the industry.
- **Segment 2:** The moderate R&D-intensity segment of the industry comprises companies manufacturing special purpose chemicals, such as dyes, paints, food additives, photographic materials, with moderate innovation expenditures. Many of the products are mature and involve large scale, as opposed to batch production outputs. There continue to exist opportunities for smaller companies to grow as niche producers or suppliers to global production networks, despite the presence of large international firms in this segment.
- **Segment 3:** The high R&D-intensity segment comprises companies that operate in high value added, low-volume chemicals. This includes pharmaceuticals and products from frontier areas of development like biotechnology and nanotechnology. In this segment growth is driven by excellence and understanding at the molecular level. New spin-off companies from research institutions and universities contribute to this segment.

First we observe that globalisation of the chemical industry and the "commoditisation" of many chemicals mean that price advantages lie with scale economies and large, low cost operations. In the field of petrochemical processing the small scale and inefficient plants in Australia are increasingly unable to compete with large complexes established in the Asian region, in countries like Singapore, Korea and China. Moreover, there are few inducements for multinational companies to further develop competitive size plants in Australia following from the generally non-interventionist industry policy approach by Australian governments.

Second, the chemical sciences are no longer a strictly isolated discipline. Today it is necessary to address the pervasiveness of chemistry across a whole spectrum of activities. For example, the core technologies in fuel cells are electrochemistry and catalysis and such activities stand to revolutionise the transport industry, not the chemical sector. Companies in the industry have the opportunity to explore more ways to use their knowledge assets, e. g. in the way they deliver their product line, manage their intellectual property, or operate across a wider section of the industry value chain [38].

Third, the growing importance of partnerships and collaboration are evidenced by the surge in the growth of R&D and technology based alliances across the globe in recent years. This has become particularly significant over the past decade in the area of pharmaceuticals. It is generally acknowledged that Australia does not possess the resources necessary to take a new exploratory drug compound through the maze of phases and approvals necessary to bring such an advanced product to market. As a consequence, Australian businesses have been quick to realise the need to network and form alliances with the major pharmaceutical houses. Some successes have been achieved and there are many more in the pipeline where the alliance strategy must become second nature. In turn, such a strategy demands that the source of the idea (in Australia) must have strong intellectual property rights in order to gain the complete advantage from commercialisation. The growth in strategic alliance formation both within and external to Australia accelerated Australia to number one in the world in the number of alliances formed on a per capita basis [39].

Lessons from Experiences

In pursuing the case study approach we have examined in detail the innovation experiences of a range of successful companies and sought to determine their common behaviours in order to seek wider insights into current innovation processes within the Australian chemical industry. In addition we have drawn on the findings of the two Government Action Agenda Reports [22, 23], and on the experiences of other industry contacts. A number of important generalisations emerge from this collective information – notably the ingredients for the successful sustainability of Australian firms in the chemical industry.

The data reveal a considerable shift in the mindset within the Australian chemical industry, arising primarily from recognition of the need to focus on wider global markets. The successful companies demonstrated that their positioning in the international industry "system" was critical, and many made these moves to internationalise early in their development phase – the born-global companies [29]. Internationalisation not only underpins companies' networking and relationship building, but also the way in which they develop their knowledge base and capabilities. Successful innovation is clearly associated with:

1. working within the industry value chain,
2. engaging in the global value chain of other industries.

A related but distinct theme is "leveraging knowledge from others", especially in product development and in the process of marketing. This emerged from the case studies as an important phenomenon. It is consistent with the views of Chesborough on "open innovation" or drawing on external sources for ideas, e. g. from other companies through research or technology alliances or from public sector research institutions [20]. We consider that the formation of new companies from the public or private sector fall into these categories since "spin-offs" most frequently involve licensing the technology from a parent company or a research institution.

In summary, the two additional innovation strategies adopted by Australian chemical companies to attain a world competitive position in the chemicals sector in the post-protectionist era have been:

3. developing an integrated packaging concept for their products and services, and
4. leveraging the knowledge of others.

Other authors [39, 40] have referred to "leveraging the knowledge of others" in the broader sense as "systems integration" – combining the best from the world stable of innovative solutions, and creating from the combinations a unique and new product, system or service [29, 39].

Each of these mechanisms is illustrated in the next Section with reference to a cross section of case study examples.

Innovation Strategies

Working Within Existing Global Value Chains

The pharmaceuticals industry is a global value chain dominated by just a few large pharmaceutical houses. Each stage of the innovation process is a separate market within the overall pharmaceuticals market. At each stage value is added, innovation takes place, resources are used and people are employed. One of the consequences of globalisation in this industry is that companies choose the location of their activities at each stage according to the perceived benefits. This creates opportunities for companies across the globe to contribute at various stages of the global chain activities.

The pharmaceuticals industry is the highest-growth and highest profitability segment of the chemical industry. It is an innovative knowledge-based segment with high R&D intensity, and a skilled workforce. While not large on an international scale, Australia makes significant investments in the development of a local pharmaceuticals industry - the human pharmaceutical industry is reported to have had a turnover of AUD 3.7 billion in 2001, a workforce of 8,400 people. Exports represented over AUD 1.4 billion [23].

The industry in Australia has also been supported by a series of federal government programs in recent decades. These draw on the leverage available through the Pharmaceuticals Benefits scheme to provide offsets in pricing against commitments to research and development, manufacture and exports. Thus the first of these – the Factor f program was introduced in 1988, and modified versions of this incentive have followed, including the PIIP program in 1999 and then the P3 program in 2004. Under the Factor f program there was a marked increase in R&D in Australia, and this led to a strong and growing position in discovery research. Australian capacity in clinical development grew under the influence of the later programs, but there has been limited net effect on investment in manufacture [23]. However, Australia has strengthened its position in recent years in the research-based identification and preparation of new chemical entities. The industry view is that this was directly influenced by government programs, notably the former Factor f program. This provides an opportunity for Australian endeavour to contribute to the international industry and to secure a position in the global value chain. Australia's capacity for conducting clinical trials also increased with the development of new facilities.

The well known drug development "funnel" for human pharmaceutical production emphasises that there may be many target/discovery drugs, but only a few make the grade through the process to market. Drug discovery has traditionally been focussed on large scale assaying of chemicals from natural sources, but increasingly this approach is being complemented by the design and molecular synthesis of drugs on a more targeted basis. In addition, combinatorial chemical techniques have become common-place in academic research, but are not as yet frequently used in the pharmaceuticals industry. Australian software developments (chemometrics) provide a mechanism for the identification of lead compounds from the complex mixtures involved (Scimetrics Ltd. and CSIRO) [41]. The interest of the 'big pharma' companies is in drawing on fresh streams of research, often stemming from the public sector research institutions as a source of new chemicals for testing. The manufacturing and marketing phase comprises four steps: the synthesis of the basic chemicals, the high value-adding step of manufacturing active ingredients, formulation, and finally packaging and distribution.

The 'big pharma' operate across the full value chain, but there are also "safety gates" to international markets, including the US Food and Drug Administration (FDA). Successful drugs can achieve global markets of two or more USD billion dollars per year, but the path to success is narrow. The number of new chemical entities (these are the active ingredients which deliver the therapeutic benefit) finally cleared to enter the market is small, just 20 new chemical entities received FDA approval in 2004.

Australia has a few pharmaceutical manufacturing plants mainly involved in formulation and packaging, bolstered recently by GlaxoSmithKline's decision to manufacture Relenza™ in Australia. Basic chemical production is generally done in low cost countries like India and China; the active pharmaceutical ingredient (the main value adding step) is mostly done in countries that offer tax advantages like Ireland, Puerto Rico and Singapore. The subsequent steps of formulation and packaging are low value adding and can be done anywhere.

The big pharma companies generally choose to take most of their profit into the country in which they manufacture the active pharmaceutical ingredients. There has been a migration of production capacity to Singapore in recent years in response to tax incentives and subsidies. Over AUD 2.5 billion dollar has been spent on new plants by Merck, Sanofi-Aventis, GlaxoSmithKline, Wyeth and Pfizer, but until very recently there was no comparable investment in Australia for a decade. Australia does have the capacity for small contract manufacturing at IDT, in radiopharmaceuticals at ANSTO, and in the extraction of alkaloids at a small number of research companies.

Specific Australian Developments in Pharmaceuticals

IDT: The Institute of Drug Technology Australia (IDT), based in Melbourne with an annual turnover of about AUD 21 million, has secured a successful niche in the high-value added stage of manufacturing active pharmaceutical ingredients .When IDT commenced operations in 1986 it provided analytical and other services to the pharmaceutical industry. IDT now manufactures active pharmaceutical ingredients for clients from many countries, and conducts the entire post-discovery pharmaceutical life cycle. That is, IDT can take a new chemical entity from the laboratory scale to full-scale production, including the conduct phase I - IV clinical trials. There is a trend for pharmaceutical companies to outsource some or all of their research and development and clinical programs. IDT built a business around this growing trend, and its success is based on the strategy of achieving and maintaining the highest levels of quality, the latter by meeting international Good Manufacturing Practice (GMP) standards. IDT's quality systems were designed to exceed all international regulatory requirements and passed scrutiny from various regulatory bodies, including the US FDA.

CSL Limited [26] is another Australian company which operates across the full value chain, although this is mainly in the niche areas of plasma products and immunotherapy. CSL is the one company in Australia that is vertically integrated and active in all points of the value chain with a coherent R&D strategy in the area of immunotherapy. CSL's strategy has involved major acquisitions that have placed the company in a dominant position in blood collection and blood plasma processing in many international markets. The CSL group currently has an annual turnover of about AUD 2.8 billion, and has major facilities in Australia, Germany, Switzerland, the USA and Japan, and a staff of 7,000 employees working in more than 25 countries.

Biota Holdings [26] is one of a very small group of companies worldwide that have brought biotechnology medicines from research to commercialisation. For other Australian companies the business opportunity in the discovery phase is the generation of new chemicals through research as candidates for further testing and evaluation by the 'big pharmas'. The level of eventual success is low given the small number of chemicals that make it through the extended testing and approval process. The innovation strategy adopted by Biota involves the formation of strategic alliances on the back of a strong intellectual property portfolio of drug compounds. Biota is currently active in at least three additional alliances in Japan and the USA.

As a note of caution, of the success stories of bringing drugs from the discovery phase into international markets, only the Biota product Relenza™, and the colony stimulating factor (CSF) hormone cancer medical product based on research at the Walter and Eliza Hall Research Institute have so far made the grade; and it is only the recent scare and resultant drug stockpiling that has led to the manufacture of Relenza™ in Australia. However, in neither of the successful drug cases is a significant part of the value chain owned in Australia.

Thus, Australian companies also need to find a way of leveraging their discovery capability so that the nation owns a larger slice of the value chain. The challenge is to focus on those parts of value chain where the local industry can become among the best in the world and build mutually beneficial partnerships. Opportunities for greater efficiency lie in sharing resources, bringing companies of sub-critical size together, and mobilising the public R&D needed to capture more value in the global value chain.

Engage in the Global Value-Chain with Other Industries

As mentioned above, the chemical sciences are pervasive and contribute significantly to the growth of other international industries – e. g. minerals, agribusiness, health products, transport and printing. The minerals and agribusiness sectors are leading export sectors for Australia and leading edge users for new and improved technologies. The leading sectors in manufacturing also offer opportunities for inputs from the chemical industry.

For example, polymers are integral to many products produced for export. There are opportunities for Australian companies to play a role as part of the supply chains for such industries. An example is the automotive industry which has high level requirements for a range of polymer components (which account for up to 8 % of car body weight) with each of the major car companies based in Australia having a select set of specialty suppliers. The situation is replicated with other export industries producing products which involve polymer components – the opportunity exists for small and emerging companies to build specialist roles and supply high quality products to meet demanding specifications. Examples also arise in the medical and scientific equipment area – companies such as Resmed, Sola and Cochlear require and use polymeric components produced to the most exacting standards.

There may also be opportunities for customer driven processes involving the public sector research agencies.

Specific Australian Developments

Plastic bank note technology: now in use in Australia and exported to many countries around the world was the outcome of a process initiated by the Reserve Bank and brought to fruition by researchers in the CSIRO Division of Chemicals and Polymers and Note Printing Australia. The work involved the development of a novel polymer substrate and the incorporation of a number of anti-counterfeiting devices.

Ciba Vision and Novartis: launched on world markets the day/night contact lens in 2001. This product emerged from a collaboration involving the University of New South Wales and the CSIRO (in the Vision CRC).

Moldflow Corporation: Although now headquartered in the USA, Moldflow was founded in 1978 in Melbourne, as a spin-off from the Royal Melbourne Institute of Technology and continues to have major development capability in Melbourne. Moldflow's software solutions have brought promise of "better, faster, cheaper" plastic products to major companies in various industries around the world. Designs for molds and products ranging from toys to automotive and aerospace components to medical parts and many others were simulated and optimised prior to production, saving manufacturers hundreds of thousands of dollars every year. Such solutions enable customers to predict and solve injection molding manufacturing problems in the earliest stages of product development.

Australia maintains a valuable core capability in polymer research and this should provide a platform for moving to the next generation of polymer products. The shift in the polymer research thinking is toward tailoring the properties of the polymer to meet the specific needs of the product. This entails a shift from managing the bulk properties of the polymer to managing molecular properties, and building science into the polymer. That is, chemically adapting properties to make the polymer useful for specific end uses. Some future typical examples might include a range of biocompatible polymers, polymers designed for controlled release of pharmaceuticals, and polymers for applications in human tissue engineering.

Developing an Integrated Packaging Concept for Goods and Services

It is not so long ago that chemical companies had no other thought than to make chemicals to sell to the next company in the value chain. This business model was built on the belief that the best assets (plants) would deliver the best value. However today, chemical companies must rethink where and how they compete. We can see some of these changes in the way that the Australian company Orica has integrated its explosives business into a suite of "mining services" and also in other chemical operations in Orica's "water care business". The need to think differently about the way products, and the knowledge associated with them, are sold in itself entails innovation [38].

This involves building on existing strengths and drawing on knowledge from other companies and from other fields and offering a new "package"; and subsequently delivering valuable new products and services. The value added here is in integration and product and service delivery, rather than the manufacture of individual components.

Specific Australian Developments

APS Plastics is a small Melbourne based national-award winning firm which delivers high quality solutions through systems integration. The company provides polymer engineering and design services in the areas of plastics and polymers and has achieved success in areas as diverse as the co-ordination and delivery of plastic seats for the Lisbon football stadium for the 2004 European Cup and retractable plastic syringes. It brings together the engineering product development, the selection and design of the polymer, the robotics and assembly, equipment manufacture, and manufacture of the product, drawing in specialist contractors for specific projects. The company has demonstrated that it is able to compete internationally at the top of the market with a price advantage.

Opportunities exist in Australia for companies such as APS Plastics to capture markets by drawing on the assorted skills and expertise available in the industry. John Petschel, CEO of APS talks of "the need to be global and brutal through establishing agility and performance using excellent people, effective project management, and in competitive tendering" [25].

Orica is a publicly owned Australian company with about 9,000 employees in 36 countries and an annual turnover of about AUD 4 billion. Formerly ICI Australia, the company grew in the 1950s and 60s under high tariff protection. In the 1990s it was reconstituted as an Australian company and a number of its operations were sold off as part of a streamlining process. The businesses divested included several polymers and related chemicals (PVC, ethylene, polyurethanes), technical paints, and crop protection chemicals. Orica now specialises in four areas – mining services (explosives), consumer products (paints and horticultural products), agriculture (mainly fertilisers), and industrial chemicals.

Explosives provide a good example of rethinking the business and leveraging knowledge. Orica has a long tradition in the relatively mature field of explosives, and a close association with the mining industry. Explosives were selected by Orica's first CEO as a target for growth as an international industry. Several international explosives business interests were acquired and the "package" of goods and services offered by Orica expanded. The explosives themselves are the core of the integrated blasting service, which also includes initiating systems, detonators, mobile manufacturing units, and GPS-based site management. Since 1997, Orica has become the world's leading supplier of commercial explosives and fully integrated blasting services to the mining, quarrying and construction industries. It has manufacturing operations in 28 countries including China, India, Indonesia, Malaysia, Myanmar, Philippines, Papua New Guinea, Singapore and Thailand.

Leveraging the Knowledge of Others

There is a plethora of Australian public sector research institutions which are involved in research in the chemical and biotechnological sciences, all relevant to present and future industrial development. The list is far too large to be considered in the present paper. Some outcomes can include the commercialisation of the research by an existing company, or licensing the technology to provide a revenue stream in the form of Royalty payments, or alternatively to generate new spin-off companies. Some examples follow:

Specific Australian Developments

Boron Molecular is a new, small company with a narrow product line. It was established in 2000 as a spin-off company from CSIRO, based on novel organoboron technology developed in the 1990s by Dr. Seb Marcuccio. It is now wholly owned by Xceed Biotechnology Ltd. Organoboron compounds are employed by a wide variety of large companies in their drug discovery programs. There was also a market for the new range of organoboron chemicals in the biotechnology industry and for direct sale to fine chemicals companies. The company underwent the "test by fire" of many new companies – with problems in establishing laboratory facilities, cost overruns and over-optimistic financial projections, but it has already established a business equating to several million dollars a year in selling its product on international markets. The establishment of a US office eased some, more perceived than real, difficulties of dealing with a supplier at an extended distance.

GBC Scientific [26]: Research at the CSIRO Division of Applied Physics provided GBC with the opportunity to further develop for the market an instrument now known as the MFC 2100 Micro Fourier Rheometer, which can perform analyses on volumes of less than 100 μL on samples like paints, adhesives, or on human tears. GBC manufactures and exports a broad range of scientific instruments, including atomic absorption spectrophotometers.

Starpharma Pty Ltd. [26] was established in 1996 to commercialise dendrimer technology discovered at the former Biomolecular Research Institute (BRI) Ltd. in Melbourne involving the synthesis of several biologically active dendrimers as protein mimics for pharmaceutical applications, in particular, for treating a broad range of viral and other human diseases, notably those that are sexually transmitted. Specifically, Starpharma developed the first dendrimer-based vaginal microbicide VivaGel™, which offers early hope that nanoscale dendrimers could be developed as new drug delivery platforms.

This drug is aimed at preventing transmission of a broad spectrum of sexually transmitted diseases (STDs) including HIV, herpes, chlamydia and human papilloma virus. In the USA alone, STDs including genital herpes affect more than 70 million people annually. It was estimated in 1999 that the annual cost of all STDs was more than USD 10 billion a year.

All of the above examples are of born-global companies, since they all entered the international arena almost at the point of their conception [29].

There are also opportunities for companies to work collaboratively with public research organisations on projects with agreed shared objectives and to draw on these sources of expertise. Collaboration with industry partners has been a growing feature of research conducted by CSIRO and other public research institutions including universities. It is also a core feature of the seventy or so Cooperative Research Centres which operate across the research spectrum. The value of this approach is exhibited in the success of Hawker de Havilland (HdH), a long standing core industry participant in the CRC for Advanced Composite Structures. Research conducted by the CRC and transferred to HdH was essential to the company's recent success in winning the contract to construct all the wing trailing edge devices, including flaps, spoilers and ailerons on the new Boeing 787 [42].

Outlook

We have drawn some general lessons by reviewing the common elements in successful innovation case studies of more than 25 companies operating in the Australian chemical industry, following the deregulation and globalisation phenomena that have characterised the industry over the past one to two decades.

First, it is evident from the information on R&D intensity that the prospect for Australia to develop a position as a major player in Segment 1 of the industry - the area of production of bulk chemicals is negligible in the event that the major players do not invest in the near-term in large-scale processing plants in Australia.

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Second, Segment 2 products are generally built around speciality chemicals, which do not necessarily demand high research intensity and the opportunities for Australia to make a significant mark on the world scene appears low and possibly reducing. Most of the products in Segments 1 and 2 of the industry are mature and for cost efficiencies to be gained these demand large scale processing. Where Australian companies may succeed in Segment 2 may involve yet to be identified opportunities in novel customer-driven batch production.

Third, future success in the Australian chemical industry clearly depends on Australia's capacity to change through innovation, either by drawing on its own high quality research base, or alternatively integrating capabilities from other sources. This approach is justified by the outcomes of the case studies.

We conclude that the lessons to be learned from the case studies for future opportunities in the chemicals sector must rest on at least the pursuit of four simple mechanisms of innovation drawn from the case studies. These "innovation strategies" include existing and new players (1) working within existing global value chains, (2) engaging with other globally focused industries, (3) developing an integrated packaging concept for their products and services and (4) leveraging the knowledge of others.

In other words, the evidence suggests that the preferred mechanism for sustained development of an Australian identity in the chemicals sector will best be achieved through the adoption of niche strategies. Australia cannot afford to be complacent about its "chemical future". The task at hand is an urgent one, and the urgency is for Australian industry to be more innovative in order to ensure its future global competitiveness.

From a policy perspective, we suggest that the most important lesson is that the chemical sector should not be considered as the conglomerate that statistical data collections have tended to impose on the analyses, but rather as a series of distinctly different components such as those delineated by the segmental analysis. There is a need to nurture a well connected and relevant research base, from which entrepreneurs and companies can be born with the agility and foresight to capture the opportunities that arise. Not only that, but government policies should aim to provide a supportive environment for the growth of new and emerging born global companies, and new born global activities taken up by existing companies.

We suggest that the strategies for innovation that emerge from this study are also applicable to any small country that is unlikely to be the subject of major foreign investments in the manufacture of bulk or special purpose chemicals, but which possesses a strong research infrastructure.

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Research Paper

Three-Dimensional Valuation of IP Rights

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Abstract: IP rights form the major part of the group of immaterial property assets which have been gaining importance for companies. The present paper provides a new method for valuating especially patents with respect to their monetary value, technological scope and legal importance. Several methods for value calculation and technological evaluation are discussed and a 3D-analysis based on a concrete example is presented.[1]

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Introduction

Intellectual Property (IP) rights and copyrights form part of the group of immaterial property assets which have been gaining importance for companies even though their balancing – at least according to German commercial and tax law - is only possible if they were acquired from third parties, in other words, in return for payment. This may lead to considerable distortions of competition because numerous companies, for example in the field of biotechnology, can hardly present any assets other than patents and patent applications. Their value, not only of start-up companies but also of many major players, is largely based on their treasure of patents and copyrights. According to a survey conducted by Cardoza et al. the intangible book value as a percentage of market capitalisation of the S&P 500 is approximately doubling since 1975 every 10 years and has now reached about 15 % [1]. In addition, property rights as immaterial property assets have been gaining increasing importance for the creation of liens, for example when financing R&D, or in M&A transactions.

From an accounting point of view, material and immaterial property assets may have a similar significance for a company, however, the difference, or should I say, the dilemma, becomes visible at the latest when a comprehensible valuation needs to be presented, which is able to resist the strict regulations of IAS 38 and IFRS. This can be shown by way of a simple example: If a company owns a gold mine, the deed of ownership embodies the difference between a profit amounting to "X" and no profit at all. In addition, if this company owns patents protecting a particularly environmentally sound method of extraction of the precious metal from the gangue, it is certainly obvious that no additional benefit may be generated without these patents; however, if any additional profits are generated by such patent protection depends on many other factors. Therefore, material assets exhibit a value of some or other nature in themselves, while immaterial assets, such as patents in particular, can also take the value of „zero" if they are granted world wide and even enforceable in principle. Because of a vivid interest in determining the value of protective rights as immaterial assets, and due to the fact that existing approaches from literature either refer to single aspects of valuation and/or re by far too complicated to evaluate huge portfolios we shall in the following have a new look at the three valuation dimensions of

- Monetary value
- Technological value
- Value in the patent law sense

in order to develop a pragmatic and still sustainable approach for valuating IP rights.

Monetary valuation of IP rights

In the past years, a variety of papers has been published dealing with the economic valuation of IP rights and IP portfolios, an issue of increasing importance, although the focus of these papers is on the entirely monetary valuation – we shall call it the first valuation dimension. At this point I should like to make a reference to the publication of Khoury [2] and particularly Rings [3] who has compiled an extensive list of factors which could be of significance for the value of an IP right. Basically the existing methods of valuation can be traced back to any of the three following approaches:

- Market orientation:
  Determination of the patent value using comparable patents or licenses by interaction of supply and demand on the market;
- Cost orientation or licence analogy:
  The sum of all real, fictitious and/or potential costs and expenses which accrue in connection with the development or acquisition, maintenance, defence and marketing of a patent;
- Profit orientation:
  Discounted profits, earnings or cash flows, which have been generated with the patent or can be expected in the future.

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Market-oriented approaches

Market-oriented approaches aim more at the consideration of the past then of the future. Their question is what price an IP right might reach if offered for sale. For real estate this may be a reasonable method as there are a sufficient number of possibilities of comparison for this kind of material assets. For patents, however, there is no market in this sense so that any value is speculative in the end. Therefore, market-oriented approaches usually do not yield reasonable results.

License analogy approaches

Approaches derived from license analogy can be regarded from the standpoint of both the licensor and the licensee. The first approach is comparably simple and sound provided it can use existing license income as its basis. With that, the value of the IP right (V) would result as the sum of annual license payments (l) over the duration (i) of all license contracts, from which the sum of the costs (k) for the creation and maintenance of the IP rights needs to be deducted:

(1) $$V = \sum_i l_i - \sum_i k_i$$

The only imponderability merely is the amount of annual license income.

Things look different when we carry out the determination of value according to the method of license analogy without even having a licensee. Experience shows that an active search for a third party interested in a license is a difficult undertaking, the outcome of which can rarely be predicted, and in which very different ideas about the value of IP rights to be licensed collide time and again. Accordingly, the above formula shall be completed at least by a risk factor (γ) which is between 0 and 1, and which expresses the probability of finding a licensee at all.

(2) $$V = \gamma \sum_i l_i - \sum_i k_i$$

If a contract is then concluded, the effective license income remains an arbitrary parameter even if we consider an average customary license factor because in this already hypothetic scenario we cannot make a statement on the license-relevant turnover a licensee would make. Hence the determination of value on the basis of fictitious license income significantly depends on mere assumptions on the probability of the granting of a license, on the license factor to be agreed, and on the income of the licensee. As usually none of these factors can be predicted with sufficient certainty, this method delivers completely hypothetical and therefore arbitrary values and is simply not meaningful.

On the other hand, we can use the method of license analogy in a different manner, namely by asking which costs have been saved by not depending on obtaining a license for the protected technology from third parties. The value results from formula (3)

(3) $$V = \sum_i l_i$$

in which factor (l) stands for the fictitious license expenses. The approach to determine the value by way of saving costs has the charm that it is possible to state the turnover – at least in case of already existent business. If we assume an average license factor which is customary for the technology, it is possible to keep uncertainty low, which is always involved with mere estimates. Admittedly, this approach requires that the absence of a company's own patents would imperatively entail patenting by competitors who would be willing to grant licenses at standard, and therefore bearable, conditions, which nobody can tell for sure.

Profit-orientated approaches

Amongst the approaches orientated at profits, the one is certainly of particular simplicity which implies that income and existence of a patent would stand in a direct connection, i.e. by plainly linking profits to patent protection. So the value of an IP right (V) would result as sum of the annual profit (p) over the number of years (i) in which income is received, whereby the sum of the costs (k) associated with application and maintenance of the IP right obviously needs to be deducted for the same period in time:

(4) $$V = \sum_i p_i - \sum_i k_i$$

We shall at this point ignore how reliably we can estimate the earnings performance history over the duration of an IP right or the life-time of

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the product. It should be clear though that this approach presents the “roughest possible“ generalisation that we can make for the correlation between patent protection and gains, and which in 99.9 % of all cases is certainly inappropriate as it requires two preconditions:

- A product or a product group must be already available so that reasonably realistic estimates of value can be carried out, and
- In case of lapse of patent protection, gains would approach zero.

Firstly, from the above it follows that this approach can not be applied to new technologies at all or remains completely speculative because any speculation regarding gains would be based on a hypothetic business performance, and risks in connection with product or market development would be completely ignored. However, also for established products, this approach is too short-sighted because in the majority of cases turnover and gains are not exclusively based on a patent monopoly; price, quality, production safety and technical service, etc. are of the same importance. A typical example is the generics: after termination of patent protection the profits of the previous patent holder are considerably reduced because other market mechanisms are decisive for the performance, but they rarely approach zero.

In order to evade this problem, literature suggests compensating the imponderability of this method by introduction of weighting factors, which can take values between 0 and 1. This can easily be explained by way of an example. Assuming that patent protection would cease to exist, we shall now contemplate what influence this would have on the competitive environment. If the market is attractive and strongly influenced by our monopoly, it would well be possible to assume that competitors would appear instantly, i.e. the correction factor for the likelihood of competition (f_1) would be 1. It could, however, also be possible that nothing would change in the competitive environment, e.g. because the market is not very attractive, or the technology is very specific. In an extreme case, the weighting factor and subsequently the value would equal zero because the patents would not contribute to the profit at all. Even if competitors enter the market, this does not automatically have to lead to the loss of the whole business. It is more probable that market shares need to be surrendered, and that business will stabilise at a lower level. In this case the weighting factor for the market share (f_2) might be 0.5. Similarly, more and other factors can be defined depending on the case. At this opportunity it is recommended to further take into account that the value of an IP right or a group of IP rights is usually not 20 years but it is linked to the lifetime of the respective product which can be much shorter. Therefore, summation needs to be carried out from the priority date of the patent(s) – or the beginning of use – up to the end of industrial use (t), which then leads to the modified formula (5):

$$V = (f_1, f_2, ..., f_i)\sum_{i=s}^{t} p_i - \sum_{i=s}^{t} k_i \tag{5}$$

Even if the formulae become more and more complex, there cannot be any doubt, though, that the suggested objectivity is, and will always remain, pseudo-objectivity. May turnover and lifetime be comparably reliably calculated – otherwise every business plan would be obsolete from the start – however, the assumptions connected with the weighting factors are always speculative and „soft“. The more such factors are introduced into the formula, the more we need to hope that the errors are balancing each other out. Incidentally, with the number of factors the value of the IP right automatically diminishes, which shall be illustrated by the following example:

The starting point shall be the fictitious patent-protected product *„Emulgade X“*, which is expected that it would not assert itself on the market for more than five years. For this period we shall assume an annual turnover of 10 million € with a profit contribution of 35 %. As it is a small patent family, the costs for application and maintenance shall be estimated to be not more than 100 T€, which means that we may ignore this amount, to simplify matters, in the further value calculation. Thus the value is calculated according to equation (5) as follows:

$$0.35 \cdot (10M\,€) \cdot 5a = 17.5M\,€$$

Now we need to compare the situation with and without patent protection, which requires a further few assumptions. If we act on the assumption that the probability of a competitor entering the market as soon as patent protection ceases is 50 %, this means that the result firstly needs to be multiplied by correction factor $f_1 = 0.5$. If we further assume that, in case a competitor appears, he would take from the patent owner 50 % of the market share at a constant price, or the patent owner would lose 50 % of his profits due to a fall in prices, then the result will have to be multiplied another time with a correction factor $f_2 = 0.5$:

$$17.5M€ \cdot 0.5 \cdot 0.5 = 4.275M€$$

It is obvious that the result can be shifted into any direction by suitable „readjustment“ of the soft parameters. Although this method of calculation of value does consider market factors, it is only reliable to the extent of our willingness to accept the given conditions, namely kind and amount [4].

Approach of the market share

Poredda and Wildschütz [5] pursue an interesting profit-oriented approach, in which they assume that the value of an IP right is primarily proportional to its market share which can be controlled by the patent. To this end, they employ a model of a mountain situated between the potential supplier and the market product (cf. Fig. 1).

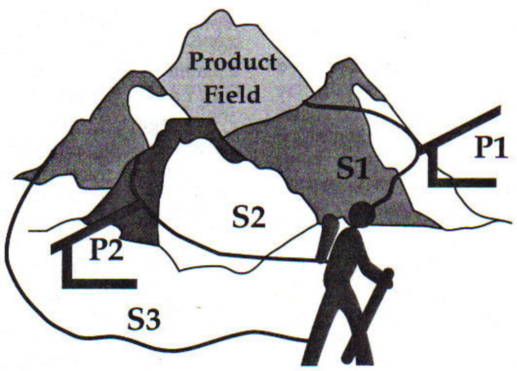

Figure 1: The path through patent landscape

According to this nice model there are various paths (S1, S2 and S3) over the mountains leading to the desired product, which vary in steepness or length and due to this are more or less attractive. In addition, paths S1 and S2 are blocked by customs facilities P1 and P2 (= patents), so that as the only working alternative path S3 remains, which however is the longest (= most expensive). The value of an IP right (equation 6) is again calculated according to this proposal over the sum of the profit aimed at multiplied by a factor δ, which results in the attractiveness of the relevant technology (a) in relation to other alternative technologies as well as forms of circumvention over the actual time of exploitation:

$$V = \delta_a \sum_{i=s}^{t} p_i - \sum_{i=s}^{t} k_i \qquad (6)$$

Furthermore, the proposed method of calculation takes into account that a product usually does not utilize just a single technology. A car, for example, comprises a motor, gearbox, braking system, electronics and much more, and all – protected – technologies behind it contribute to the profit of the finished product. Therefore, a further correction factor π is required describing the share the technology (a) contributes to the creation of the finished product:

$$V = \pi_a \delta_a \sum_{i=s}^{t} p_i \sum_{i=s}^{t} k_i \qquad (7)$$

Ultimately, the authors point out an issue which receives far too little attention in the monetary or, respectively, technological valuation of IP rights: the patent strength, which is described by weighting factor λ for technology (a), and itself is composed of a sum of individual factors, for example, the extent of protection, patentability, the possibility to prove infringements, remaining duration, etc. In closing, the following equation results (8):

$$V = \pi_a \delta_a \lambda_a \sum_{i=s}^{t} p_i \sum_{i=s}^{t} k_i \qquad (8)$$

However, at the end of the day this calculation method does also constitute nothing more than a profit-oriented approach, in which merely the selection of correction parameters is different. The inclusion of a parameter that corresponds to the strength of the IP right is certainly reasonable, but only if set in suitable proportion to the remaining control parameters, as the following example shows. Patent strength λ_a, accordingly, is the product of only three sub-parameters, to simplify matters, which are defined as „Probability to grant λ_{a1}“, „Scope of protection λ_{a2}“ and „Remaining lifetime λ_{a3}“, each of which may take any value between 0 and 1. The considered IP right is in the 7th year of its duration ($\lambda_{a3} = 0.66$), and an opposition has been filed. After restricting the original claims version to a preferred form of embodiment ($\lambda_{a2} = 0.5$), novelty is established, and the chances that the Opposition Division recognises inventiveness, however, are 50:50 (λ_{a1} = 0.5). For patent strength (9) there would result:

$$\lambda_a = \lambda_1 \lambda_2 \lambda_3 = 0.66 \cdot 0.5 \cdot 0.5 = 0.165 \quad (9)$$

If patent strength according to formula (9) were incorporated as an additional correction factor in the calculation of value for *Emulgade X* according to equation (5), in the above calculation example the value of the IP right would diminish from 4.275 M€ to a little more than 700 T€. If this approach is followed consequently, the introduction of only a few additional control parameters – each of which may have its merit – will ultimately bring the result to zero. This should not be the result of a reliable valuation.

Technological valuation of IP rights

As shown in the previous considerations, the monetary valuation of immaterial assets which aims at assigning them a value in Euro and Cent, exhibits the generic problem that the calculation basis largely depends on assumptions and is therefore reliable to the extent of how reliably the propositions can be regarded. However, this also provokes the question whether it is possible to at least support the monetary valuation by a kind of counter calculation. Therefore, a further valuation dimension is required.

To this end, business-oriented valuation methods for the valuation of IP rights have been catching on since the 1980ies. The following approaches have proved to be particularly interesting for it:

- Patent audits
- Life cycle analysis
- Portfolio analysis

Auditing of patents

The patent audit firstly aims at the compilation of the patents available in a company, and then to determine technological, legal and value-relevant information on an individual basis [6]. Up to now, however, this method has basically been used to facilitate decisions on maintenance or abandonment of IP positions, and to determine the potential of licensing out a company's own technologies.

Life cycle analysis

The success of a product on the market shows, over time, a characteristic bell-shaped course which passes through 5 stages:

1. Introduction (investments still prevail)
2. Growth (above-average growth rates)
3. Maturity (growth rates decrease, profits consolidate)
4. Stagnation (turnover and profits decline)
5. Decline (turnover and profits collapse).

The life cycle of a product can be associated to the life cycle of the respective IP right which, however, shows a slightly different course:

1. Application (benefits are still low because it is not clear yet whether and in which form a patent grant will occur).
2. Maximum benefits as soon as patent grants
3. Decline (abandonment, revocation, expiration)

Due to the different gradients it is not possible to make the life cycles congruent, however, they can be harmonised – with varying success - as the three following examples demonstrate. Fig. 2-4 show the sales of the respective product in [T€] and the corresponding patent protection for this product over the time. Patent protection starts at a low level at the time the application is filed and increases to a level of 100 % until the patent is finally granted and valid. It goes down to zero once the patent application is finally rejected, abandoned or the patent has been revoked or is expired.

- In the first case, product A displays a broad bell-shaped gradient of gains over quite long earnings performance duration of 20 years. At the time of market launch, however, the pertaining IP right was filed 8 years ago and granted 5 years ago. Protection expires in the phase when the company makes the biggest gains with the product. In the following, the company faces the danger of competitors appearing and of market shares declining. This example shows that the market launch simply occurred too late.

- In the second case, product B shows a short success story and thus a narrow bell-shaped curve. Also this product is profiting from patent protection only to a small degree because it is already in decline when patent protection displays its biggest effect due to grant. As a consequence, the IP right should rather be abandoned because it cannot be exploited any more.
- In the third example, maximum gains and maximum protection coincide temporally. Hence, market success and patent protection are synchronising.

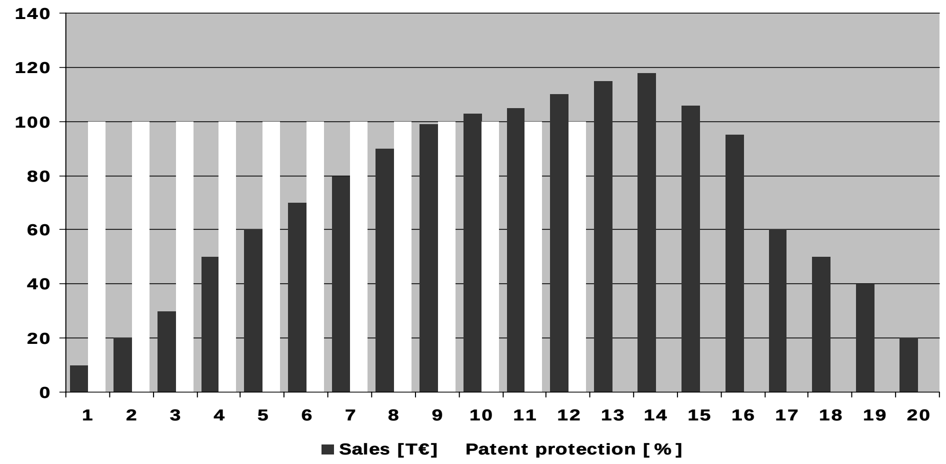

Figure 2: Life cycle analysis: example for a late market launch

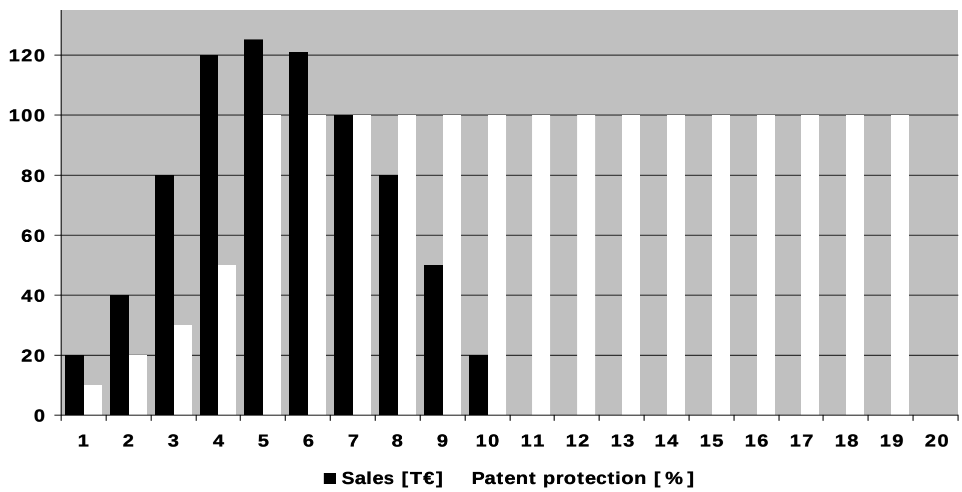

Figure 3: Life cycle analysis: example for a short product cycle

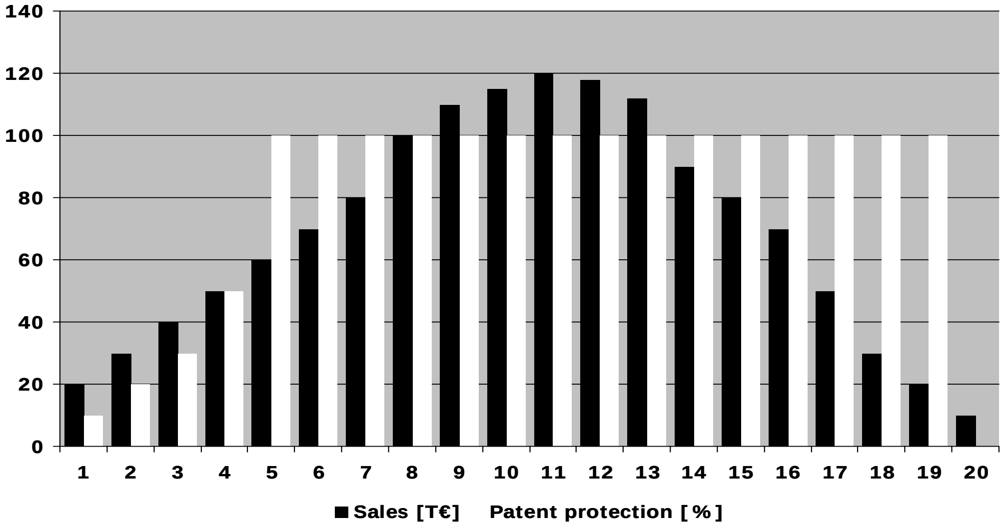

Figure 4: Life cycle analysis: optimum synchronisation

Life cycle analysis is an interesting tool for the visualisation of the connection of market mechanisms and patent factors. In addition, it is useful when evaluating the question whether to maintain or to abandon IP positions as it considers market-relevant aspects. However, for valuation purposes it gives only limited information as it does not reveal any causal interrelation between market success and patent protection.

Portfolio analysis

Systematic evaluation of patent information for the valuation of patent portfolios is a discipline at the interface of business administration and intellectual property law which has been gaining increased significance in the past years. Meanwhile, there exist a number of studies revealing a direct connection between patent protection and corporate performance (cf. Table 1):

In addition, in a further empirical examination that was carried out in 2003 at the Graduate School of Management in Vallendar, Ernst und Omland could show that a direct correlation exists between a professional patent management, technological leadership, and corporate performance, particularly considering ROI aspects [7].

In doing so, the method of portfolio analysis is not new but it goes back to a model of the Boston Consulting Group from the late 1960ies, setting up a matrix of market share and market growth. In a patent portfolio analysis, success factors for the value of an IP portfolio of a company are determined and compared to the ones of its competitors. Table 2 shows a number of success factors or „Key Success Indicators“, their definition from literature and their meaning which have proven to be useful in describing the patent situation of a company in the past [13]. Of particular importance is the parameter „patent strength“ which is defined as the product of „patent quality“ and „patent activity“.

While patent activity stands for nothing else than the number of patent applications in a defined segment, various factors have influence on the parameter of patent quality [14].

- Ratio of granted and pending IP rights,
- International scope, usually related to the triad Europe, U.S., and Japan,
- Technological scope, usually focused on the number of IPC classes an IP right is assigned to, and
- Temporally weighted citation frequency in examination proceedings.

Year ,Author	Group	Result
Deng, Lev [8] 1999	388 companies from the fields of pharmaceuticals, chemistry, and electronics	Connection between market value and citation frequency of the company's patents
Hall, Jaffe [9] 1999	4000 US companies of differing fields	
Lerner [10] 1994	173 venture capital financed biotech companies	Technologically broad patents promote the performance of a company
Shane [11] 2001	1397 patents of the MIT	Patent quality correlates with the chances for commercialisation (e.g. by licensing)
Ernst [12] 1996, 2001	50 mechanical engineering firms	The higher patent quality is, the stronger is the influence on turnover development. Companies with first-class patents are more successful than those doing without patent protection or which do not pursue a patent strategy approach.

Table 1: Connection between patent protection and corporate performance

Key Success Indicator	Definition	Meaning
Patent activity (PA_{iF})	Patent applications *(PA)* of a company related to a technological field (TF)	Indicator for R&D expenditures of a company
Technology share*	PA_{iF}/PA of all companies in the technological field	Technological competitive position of a company in TF
R&D focus	PA_{iF}/number of companies *(i),* total number of patent applications	Importance of the technological field for a company
Co-operation intensity	Number of joint patent applications with co-applicants in TF	Access of a company to external know-how
Share of granted patents (Q_1)	Number of granted patents of a company in TF	Technological quality of the company's patent applications
Technological scope (Q_2)	Number of designated IPC classes in a company's patent applications	
International scope (Q_3)	Size of patent family and share of triad (US, EP, JP) patents	Economic quality of a company's patent applications
Citation frequency (Q_4)	Average citation frequency	
Average patent quality (PQ_{iF})	Sum of all indicators of patent quality (Q_1-Q4)	Average total quality of all patent applications of a company in TF
Patent strength (PS_{iF})	Product of average patent quality (PQ_{iF}) and patent activity (PA_{iF})	Technological strength of a company in TF
Technology share**	Ratio of the patent strengths of all companies in TF	Competitive technological position of a company in TF (qualitative)
Relative technological share	PS_{iF}/*Max.* patent strength of a company in TF	Distance of a company to the technological leader in TF

Table 2: Success factors for the evaluation of the patent situation of a company

The following Figure 5 shows criteria for three companies (Beiersdorf, Cognis and L'Oréal), taken from a previous analysis of the market situation in the area of cosmetics covering the period 1995 to 1999:

- Number of European patents and patent applications
- Number of US patents and patent applications
- Number of Japanese patents and patent applications

In the evaluation, the highest value reached is set at 100%, and the values of the other companies are related to it. For example, within 1995 to 1999 the French company L'Oréal has filed 77 % of its new patent applications either priority founding or in the course of the foreign-filing with the European patent office, while this was true for the second company Cognis only in 60 % and for the remaining third company Beiersdorf in 65 % of their cases. Consequently, the filing activity for the parameter "Europe" was set to 100 % for L'Oréal and the other companies achieved percentages relatively to their share. This kind of presentation, which also can be done in a spider graph, allows a quick view on some of the main key success parameters for patent strength and makes a comparison between companies easy.

Patent portfolio analysis offers the advantage that the technological position of a company can be reliably determined on the basis of objective information from public databases. In addition, this method is sufficiently validated by a multitude of empirical studies. Hence it is suitable for adding to the monetary valuation a second dimension, namely the technological position.

However, with respect to data gathering, data conversion into success indicators, as well as valuation and calibration, this method is technically challenging and time-consuming. Furthermore, it does not take into account legal factors, particularly concerning the enforceability of the considered IP rights.

The 3-dimensional valuation of IP rights

The monetary valuation of IP rights generically provides only pseudo-objective results. Technological consideration as a second valuation dimension according to the patent portfolio method would prove to be sufficiently valid but is technically challenging. In addition, a legal consideration as a third valuation dimension is still outstanding. It seems that this does not take us any further toward a complete consideration and, particularly, a pragmatic approach for the three-dimensional valuation of patent portfolios.

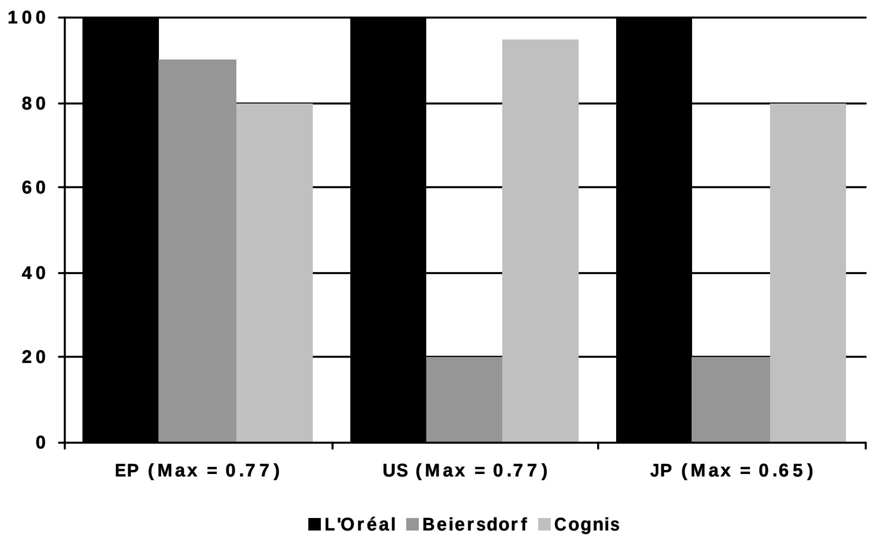

Figure 5: Patent valuation: Performance benchmark within the technology field hair treatment (1995-1999)

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In fact, however, the presented methods do contain all necessary tools to reach a solution.

In the valuation model presented below, monetary valuation according to the profit oriented approach is combined with the technique of matrix consideration of portfolio valuation, and we will play through this model using the case of the fictitious product *„Emulgade X"* mentioned in the beginning, the patent portfolio of which was assigned a monetary value of 4.275 M€ (cf. above).

In the most simple case, firstly a co-ordinate grid is to be spanned, the axis are to be labelled „Technological value" and „Value in the patent law sense", which is followed by assigning to each of those two valuation dimensions a value on a scale from 0 to 100 in order to reach a positioning of the considered IP right in the diagram. The higher the co-ordinate is positioned in the upper right-hand corner, the higher is the value of the IP right. Much as a pragmatic approach is needed, this one would obviously be too short-sighted. Nevertheless, it is a suitable method in order to bring us a step closer to our goal. To this end, it is firstly necessary to dissect the two valuation methods which span the co-ordinate grid into individual factors, as is exemplarily shown in Table 3 for 4 parameters in each case. The number and selection of the parameters are up to the evaluator, however, one should take care of those parameters which may show an interaction, such as "scope of protection" and "chances for grant": the broader the claims of a patent application are, the lower usually is the chance to have these claims granted without amendments. On the other hand, once the patent has become granted and valid, broad claims have a superior impact on the quality.

By compilation of target questions, on the one hand, it is possible to make transparent which factors were consulted for the technological and, respectively, valuation of an IP right in the patent law sense. Furthermore, it is now easier to assign a value to each parameter. However, before this happens we need to consider that the factors contribute to the individual valuation dimension to a varying degree – thus they need to be weighted as shown in Table 4.

Technological value	**Value in the patent law sense**
Chances for realisation?	High chances for grant?
Development of basic technologies or incremental improvements?	Broad scope of protection?
Alternatives available?	Forms of circumvention available?
Danger of imitation by the competition?	Evidence of infringement possible?

Table 3: Parameters for technological valuation and valuation in the patent law sense

Technological value		**Value in the patent law sense**	
Chances for realisation?	0,50	High chances for grant?	0,70
Development of basic technologies or incremental improvements?	0,20	Broad scope of protection?	0,15
Alternatives available?	0,20	Forms of circumvention available?	0,10
Danger of imitation by the competition?	0,10	Evidence of infringement possible?	0,05
Total	1,00	Total	1,00

Table 4 Parameters for the technological valuation and valuation in the patent law sense, and their weighting

Now, we can start evaluating the individual factors. To simplify matters it shall be assumed that the product is protected by a single patent only. We shall further assume that the fictitious product *Emulgade X* represents an emulsifier, particularly suitable for the cosmetic industry, and is composed of components A and B, wherein it is required for admix the two components above a particular temperature, and to cool the mixture down afterwards. Incidentally, the product shall be utilised in the emulsification of additives, which are applied in very different areas of use, such as in leather technology and as herbicides. There are a number of other emulsifiers in the market, but in comparison with *Emulgade X* they require larger quantities. Therefore, after launch, this product has established itself quickly in the market and bitten off a considerable market share from the competition. It is therefore no wonder that competitors are now trying with all means to destroy the pertaining European patent in the course of the opposition proceedings.

After the product is introduced in the market, the factor „Chances for Realisation“ needs to be set at 100 points in a scale from 0 to 100 points. According to the quick market success much speaks for it that the product is rather the result of a basic development than of an incremental improvement (70 points). Alternatives do exist, but as they constitute inferior forms of embodiment (50 points), this would result in a relatively high danger of imitation by the competitors (90 points). The patent is under opposition. As man is known to be in God’s hand at court and at high sea, we shall not give more than 50 points to Chances for Grant. If the claims are not limited to the literal mixture of products AA and BB, but refer to the more generic groups A and B, and also cover the method of production and the different uses, we can certainly give 80 points to Scope of Protection. Forms of Circumvention can not safely be excluded (50 points), but by way of analysis of the finished products the issue of possible infringement can be easily clarified (100 points).

In the following Table 5 there are shown the factors, their weighting (f_1) and evaluation (f_2) as well as the values resulting by multiplication (f_s), the result of which are the final values F_T and F_P for the two valuation dimensions.

Hence the technological value of the IP right is clearly higher than the value in the patent law sense, which can be explained by the fact that the patent-protected product was already introduced into the market (strong impulse for the technological value), the pertaining patent, however, is under opposition (which decreases the value in the patent law sense). Obviously, this matrix can only provide a momentary snap-shot: for example, if the product needs to be taken off the market because it might be infringing regulatory provisions, the technological value instantly approaches zero. If the patent survives the opposition/appeal proceedings without any amendments, the factor in the patent law sense increases to almost 100 %. Obviously also this valuation method is flawed by the fact that it conveys only a pseudo-objectivity, and a „fine-tuning“ of the result is possible by making changes to the absolute value or the weighting.

Technological value				**Value in the patent law sense**			
Factor	f_1	f_2	f_s	Factor	f_1	f_2	f_s
Chances for realisation?	0,50	100	50	Chances for grant?	0,70	50	35
Development of basic technologies?	0,20	70	14	Broad scope of protection?	0,15	80	12
Alternatives available?	0,20	50	10	Forms of circumvention?	0,10	50	5
Danger of imitation?	0,10	90	9	Evidence of infringement possible?	0,05	100	5
Total F_T			83	Total F_P			57

Table 5: Parameters for the technological valuation and valuation in the patent law sense, and their weighting

However, due to the fixed determination of the valuation factors and their weighting, this danger is limited because every condition and every weighting can be questioned in case of doubt. With a sufficient number of parameters, the errors resulting from too pessimistic or too optimistic expectations usually level each other out.

The result is illustrated in Figure 6 below. Technological valuation and valuation in the patent law sense span a coordinate grid in which the considered IP right takes its place. The third dimension – i.e. the previous monetary valuation is symbolised by the size of the circle: the higher the monetary valuation, the larger the diameter. However, this approach starts to become interesting when comparing different products this way, as is shown in Figure 7.

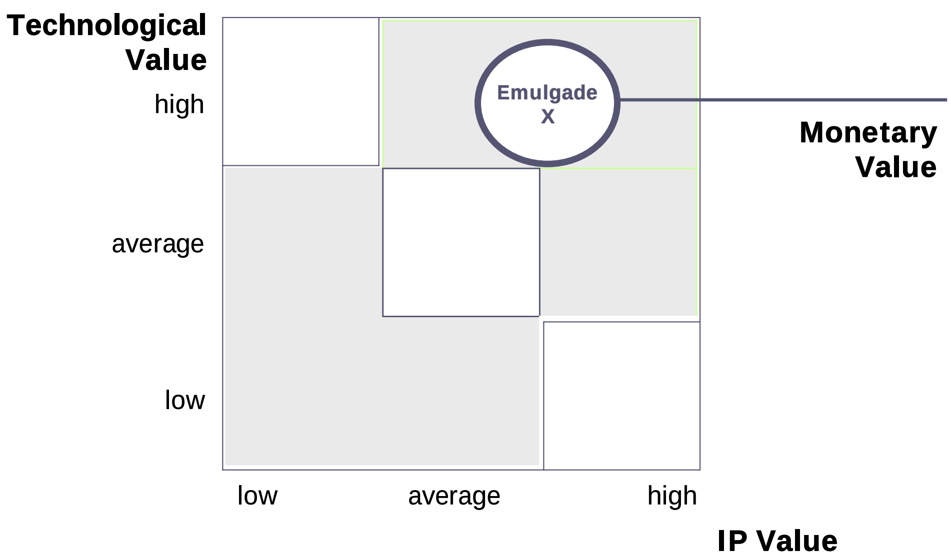

Figure 6: 3D-depiction for the example product Emulgade X

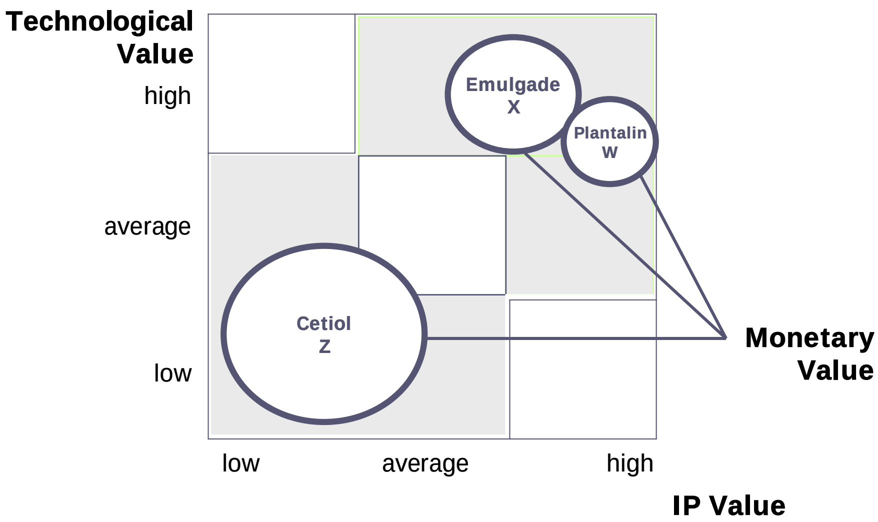

Figure 7: 3D-depiction of a valuation landscape

The fictitious product *Cetiol Z* is positioned in the lowest quadrant and thus possesses both a very low technological value and a low value in the patent law sense. Even so, it has been assigned a monetary value twice as high as the value of the product *Emulgade X*. This may signify that the product has a very high turnover which is dependent on patent protection only to a small degree. On the other hand, it may also be an indication that the assumptions in the monetary valuation were too optimistic. Conversely, the fictitious product *Plantalin W* possesses both a very high technological valuation and a high valuation in the patent law sense, however, its monetary value is considerably lower than the one for *Emulgade X*. Provided that the assumptions for the valuation were correct, such picture is typical for products in their first two phases in their life cycle. A coherent result is always available in case those technologically first-class patents with a good valuation in the patent law sense also show a comparably positive monetary valuation. In case of divergence the facts need to be questioned.

Summary

In the monetary valuation in Euro and Cent we will have to take into account that the determination of value is subjective and may differ depending on the assumption. This problem is, in a manner of speaking, sui generis, i.e. it is left to the evaluator which parameters he wishes to consult for the determination of value, as long as these are transparent and are understood and accepted by the counterpart at whom this evaluation is directed. Among the business-oriented approaches, the patent portfolio valuation on the basis of information retrieved from patent data bases is convincing due to its comparatively high objectivity. However, high technical efforts and the lack of a component in the patent law sense are disadvantages.

In order to meet the expectation to carry out a three-dimensional valuation of IP rights from a monetary, technological, and legal perspective with a justifiable effort, a two-dimensional matrix consideration of technological value and value in the patent law sense might be suitable, in which each of these dimensions is dissected into individual valuation factors, which are weighted and assigned a value. This two-dimensional depiction in a co-ordinate grid can be supplemented by the monetary valuation as a third dimension, in which a cost-oriented approach offers most advantages among the different methods.

This approach has the charm that it can be carried out with a manageable effort and has been successfully implemented in 2005 as an important strategy and management tool within the Cognis Holding. Still it must be clear that it does not provide an objective picture either, a pseudo-objective picture at best and a snapshot in addition. Because of the large number of different valuation factors and the special transparency of the calculation basis connected with this method, preconditions are given that a high degree of acceptance can be reached between the evaluator and the person the valuation is directed at – which is still the decisive requirement that an IP right valuation fulfils its meaning.

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Practitioner's Section

The Future Belongs to Renewable Resources

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Abstract: Degussa has held its first conference on natural raw materials and their importance for the chemical industry. The drift of the conference was that there is a plethora of possibilities for corn, plant oils, enzymes, and bacteria and that these possibilities are far from being exhausted.

Introduction

Day after day, the world economy has been feeling the impact of crude oil prices, which are ranging between US$ 60 and 70 per barrel. But these same prices have also drawn more attention to renewable resources. The chemical industry, for example, already meets up to 8 percent of its demand for starting materials with renewable resources. “The change from fossil to renewable resources is one of the biggest challenges we face in the next 50 years,” said Dr. Alfred Oberholz, deputy chairman of the Management Board of Degussa AG, at the BioRenewables Days.

Over 170 professionals from Germany and abroad met at the Marl Chemical Park for the Degussa-sponsored event held on March 14th and 15th. In addition to Degussa employees and politicians, the conference attendees included countless scientists from universities and research institutes, as well as representatives from companies active in the area of renewable resources. For the two days of the conference, the experts focused on the industrial use of biorenewables, oils, fats and surfactants, and white biotechnology. Politicians on both the national and European level have recognized the need for all-out efforts in research and development to expand the use of renewable raw materials.

Financial assistance through the next EU framework program

“All the leading companies have announced their investment in the use of renewable raw materials,” said Dr. Christian Patermann of the Biotechnology, Agriculture and Food Directorate General of the European Commission. The important thing now is that Europe play a key role in future developments.

This is why the European Commission in 2005 incorporated proposals and requirements for biorenewables within the 7th EU Framework Program for Research, that covers the period from 2007 to 2013. “We in the EU must promote better and stronger industry-oriented research,” said Patermann. To this end, the EU Commission has planned to increase European investment in research and development to 3 percent of the gross domestic product, and strengthen private research. Another proposal is the creation of a Europe-wide network to coordinate the wide range of activities. According to Patermann, there’s another figure that underscores the need for the “old continent” to act: “In the United States, investment in industrial biotechnology is ten times higher than in Europe.”

Dr. Peter Paziorek, parliamentary state secretary in the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV), stressed the importance of renewable raw materials for Germany: “Biorenewable products reduce environmental pollution, because they lower CO_2 emissions and reduce the amount of waste.” Not least, the cultivation and use of renewable raw materials ensure that the domestic agriculture and forestry industries have alternatives in production and income that benefit “the rural areas as a whole.”

An annual € 54 million from the government

According to Paziorek, the BMELV is earmarking an annual € 54 million for future research, development, and demonstration projects, as well as for market-launch projects. Despite cost-cutting pressures, this amount has already been budgeted for 2006. As in the past, the project will be sponsored by the Agency of Renewable Resources (FNR), which was established in 1993 as an initiative of the federal government. Since its inception, the organization has promoted nearly 1,700 research and development projects.

FNR director Dr. Andreas Schütte took stock of the current biomaterials situation in Germany. Last year, the country grew about 1.4 million hectares (roughly 3.5 million acres) of renewable resources, which corresponds to about 12 percent of domestic farmland – a nearly five-fold increase since 1993. And in 2002 (the most recent figures), about one quarter of domestic timber, or 55 million cubic meters, went to bioenergy. “About 2.7 million metric tons of renewable resources go into bioproducts in the chemical, pharmaceutical and natural fibers industries,” says Schütte. The chemical industry accounts for the lion’s share of 2 million metric tons. “This value contrasts with the roughly 17 million metric tons of petrochemical resources currently used by the German chemical and pharmaceutical industries," says Schütte. Imports still account for the largest percentage of renewable resources. Only one-third comes from domestic crops.

In Germany, Schütte sees opportunities for renewable resources in four areas: biolubricants, bioplastics, fine chemicals, and bioenergy. At about 4 percent, the share of biolubricants is still extremely small, although a market share of 90 percent is a realistic projection. According to Schütte, this is because "biolubricants have technical advantages that outweigh their higher costs." Bioplastics, which currently represent a negligibly small share, have a potential of 5 to 10 percent. "Based on its market importance, the packing industry will be a key consumer of bioplastics," said Schütte.

Competition for agricultural land

With enzymatic and microbial processes, the industry already produces about 5 percent of fine chemicals. "According to experts, this percentage could climb to between 10 and 15 percent in the next five to ten years," said Schütte. "Optimistic predictions even put the share as high as 20 percent over the next ten years." Finally, bioenergy includes biofuels, wood for heat and electricity generation, and biogas. "If you add up the potential of all agricultural and forest land, as well as biowaste in Germany, these sources could make up about 17 percent of all energy consumption in Germany," said Schütte. In 2003, that share was 3.9 percent.

Schütte reminds us, however, that while renewable resources have tremendous potential, they are not available in endless quantities: "consequently, there is competition between renewable resources and food production for agricultural land, as well as competition between the use of the resources as starting materials for bioproducts and for the generation of bioenergy."

Life cycle assessments can provide information about the environmental benefit of renewable resources for certain fields of application. Dr. Martin Patel of Utrecht University in the Netherlands reported on an environmental and economic assessment of around 15 white biotechnology products. In this so-called BREW project (http://www.chem.uu.nl/brew), which was conducted with several industry partners Patel and his colleagues analyzed various biorenewables for their energy consumption, greenhouse gas emissions and land use, and compared them with the values for a current petrochemical process. Some biorenewables showed very promising results. The results of the project will be published in the near future.

Dr. Michael Binder from the marketing department in Degussa's Feed Additives Business Unit reported on a life cycle assessment of technically manufactured essential amino acids for the nourishment of poultry and pigs. Based on the nutritional requirements of the animals, such essential natural animal feed as wheat, soybeans, peas and rapeseed will each result in different deficits of one or more amino acids. Pure amino acids can fill this gap quite effectively, and significantly improve the quality of the nutrition. The alternative is increasing renewable feed so that the animals receive an adequate amount of amino acids.

"We wondered which of these is environmentally safer," said Binder. So the entire process was examined, from producing the crop to filling the feeding trough. "The total balance is significantly more advantageous with the use of technically produced amino acids, because it saves feed, and it creates less environmental pollution through nitrogen-fraught liquid manure, for example," explained Binder. As a result, the amino acids can be produced quite sustainably – no matter whether chemical or biotechnological methods are used. "The biomass that would otherwise have to be added to the feed can be better used for other applications."

Sugar cane instead of crude oil

Dr. Jaime Finguerut of the Centro de Tecnologia in Canavieira, Brazil, described a country's experience with using biofuels. For over 30 years, Brazil has been running a program called Proalcool, which lays the framework for the nationally regulated admixture of 20 percent ethanol to the gasoline.

But the price of ethanol also dropped by roughly one-half between 1976 and 2005, so "we were forced to reduce costs," said Finguerut. Between 1978 and 2004, Brazil succeeded in boosting the efficiency of sugar cane production by 50 percent. According to Finguerut, "today, Brazil's sugar cane costs as low as € 25 per dry metric ton" – a figure Germany can only dream of right now. Brazil has achieved this value by spending the last 30 years conducting intensive research on improved sugar cane plants. "Between the years of 1980 and 2000, for instance, we were able to increase the yield per hectare by 2 percent per year," explained Finguerut. On the other hand, Brazil also has enough land to expand its sugar cane capacities, and, he adds, "our present Brazilian fermentation process has several important characteristics that can be used in other fermentation processes, particularly those based on sugar cane."

The fact that other countries have recognized the importance of producing renewable resources, was confirmed by the assertions made by Prof. Douglas C. Cameron, director of Biotechnology in the research division of the U.S.-based food corporation Cargill. The company also supplies the chemical industry, and is further expanding its capacities for this purpose. Take biodiesel, for example: Last year, Cargill announced that it would be quadrupling its annual output of about 110 million liters. Ethanol production is another example of Cargill's fast expansion of production capacities.

"The costs of renewable resources have either stabilized or are continuing to drop," Cameron statet. "This is why the decisive question is how much and how fast we can reduce process costs." Cargill's cost-cutting efforts are targeting biofuels as well as bioplastics and bioproducts. The Group is also interested in finding partners for this quest: "We see ourselves as a biotechnology company, as a developer of new platform chemicals. But we are not a chemistry company with access to completely different markets."

Degussa already supplies important raw materials for biodiesel. "We are the world market leader in alcoholate catalysts for transesterification processes," stressed André Noppe, head of marketing and sales for the Electrolysis Products & Alkoxides Business Line of the Building Blocks Business Unit. These alcoholates are the most efficient catalysts for such tasks as increasing biodiesel yields by 2 to 5 percent. Another group of fine chemicals from Degussa is solid and liquid antioxidants for stabilizing biodiesel during transport. According to Noppe, "each filling or transport process reduces the oxidation stability of biodiesel by one hour." Degussa's biodiesel portfolio also includes antifoaming agents and polyamides for fuel lines.

Plant breeding is a long process

Using the example of plants for producing energy, Dr. Ernst Kesten of the Einbeck-based company KWS demonstrated that renewable resources raise completely different questions from the standpoint of breeders: "Conventional plants have an inadequate energy balance, and are too expensive." This is why breeders are working on new energy plants that can supply maximum energy yield per hectare – a project that clashes with conventional breeding practices. The point now is to use the entire plant, not just increase the nutritional value of the fruit. And, according to Kesten, because the fruit no longer has to ripen, vegetation periods can be used more effectively. Kesten wants us to remember one thing, however: Breeding is a long, expensive process. "This is why it is important that breeders know the outlook for demand among future customers."

Speakers from completely different fields highlighted the wide range of applications for renewable resources. Prof. Rolf Schmid from the University of Stuttgart revealed in his presentation that, as valuable renewable raw materials, lipids make perfect substrates for biotransformation. To illustrate his point, Schmid discussed some of the lipids he and his colleagues had studied on behalf of industry, including biotechnologically manufactured substances for edible oils, nutritional supplements, and breast milk fat substitute.

Advantages of biomaterials

Dr. Rolf Blaauw of Wageningen University & Research Centre in the Netherlands also reported positive research results for functionalized fatty acids. The focus of Blaauw's research is biobased products such as adhesives, additives, solvents, and lubricants. Using epoxidized vegetable oil cured with polyacids, astounding properties for this two-component bioresin can be achieved. The institute has applied to patent the technology.

Prof. Peter Dürre of the University of Ulm, Prof. Bärbel Hahn-Hägerdal of the University of Lund, and Prof. Sven Panke of ETH Zurich emphasized the future importance of enzymes and bacteria in the production of chemicals. Dürre used the *Clostridium acetobutylicum* bacterium to illustrate its potential importance for the future production of solvents. "After the genes have been identified that participate in solventogenesis, we will be able to optimize the gene expression" Dürre said. In the past few years, various researchers have supplied important knowledge in this area, including ways of significantly enhancing the butanol production of *Clostridium acetobutylicum*.

In Sweden, Prof. Bärbel Hahn-Hägerdal researches the production of ethanol from pentoses, using yeast as the fermenting microorganism. "Our approach is to integrate process design, fermentation technology, enzyme technology, as well as metabolic and evolutionary engineering of yeast. For a biorefinery, it is crucial to find yeast strains that perform efficiently under harsh conditions," said Hahn-Hägerdal. Several strains of baker's yeast (*Saccharomyces cerevisiae*) have proven to be up to the task as demonstrated in a national Process Development Unit (PDU). In addition Sweden hosts a national pilot plant for the investigation and demonstration of complete process integration. Hahn-Hägerdal and colleagues are also researching the production of other substances, such as low molecular weight acids and chiral compounds.

For his part, Prof. Sven Panke contemplates transferring complex cellular processes to biocatalysis. The reason for this is the sometimes multistage nature of manufacturing steps in traditional fine chemistry processes, such as those used in the production of sugar-based therapeutic molecules in the pharmaceutical industry. Panke and his colleagues are researching a system of biotransformations. "The objective is to use the modular principle to build an appropriate organism to supply the desired molecule," said Panke. For this purpose, the EuroBioSyn Consortium, of which ETH Zurich is also a member, researches and adapts the dynamics of enzyme systems. The cost is enormous, but Panke is quite sure: "One day, it will be possible for a standard organism to function as a microfactory."

This same optimism imbued the entire two-day conference: Through intensive research and development, and with the right political environment, Europe can join the ranks of the serious players in the use of renewable resources. The important thing is not to try to do everything, but to step up activities that make sense technologically, geographically, and economically, so that Europe can catch up with or even outdistance other industrialized nations.

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