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Nicholas F. Derera, Natalia Nagy, and Adriana Hoxha

Chemicals Regulation and the Porter Hypothesis: A Critical Review of the New European Chemicals Regulation

Torsten Frohwein, and Bernd Hansjürgens

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Why are scientists not managers!?

The Importance of Interdisciplinary Skills in Business and Science

Abstract: Research is the translation from money to knowledge. Innovation is the metamorphosis of knowledge to money. Thus, business management and science are interdependent. That is no big news. But, in an ever faster changing economy, companies need a new type of scientist. Someone who knows not only science, but also business administration and management. Can the educational system satisfy those needs? In our opinion more work needs to be done – especially in the minds of scientists and managers alike!

Until the end of the last century the world seemed to be simple. There were those who discovered – SCIENTISTS – and those who ensured that money was made– MANAGERS. Let’s have a look at two caricatured extremes:

Scientists lived in their ivory tower – far away from reality. Specialists in their field of science, they lacked the sense for real world situations. Publications and papers were the revenues and profits of the scientist. The scientist was working on the edge of the world – the only remaining frontier. Be it physics or biochemistry, the scientist was discovering things no one had seen or known before. What compares to the thrill of publicising something new to the world?

For the manager money was not the only thing that mattered – but was definitely the one topic on his mind from morning to evening. Patents were more to his liking than publications. The manager had to see the product or process out of the research project. Not the knowledge creation, but the product sales were in his interest. He needed to coordinate and organize different aspects besides research and development. What is more thrilling then successfully bringing something new to the market?

Firms need both types of people if they want to survive in today’s fast-paced economy. And as the business environment is changing, companies are searching for new managing concepts. Many firms,

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for example, seek to streamline their development of new products – or innovations. "Innovation is one of the most often used words in business communications nowadays – and even in some scientific proposals. Only through new products, processes or applications can a company be successful over the long run" says Member of the Board Alfred Oberholz (Degussa AG).

But that is where the problem starts! The term "innovation", for example, is not at all well defined. Most scientists would probably assume the production of oocytes from stem cells described by Schöler, et al [1] as an innovation – as it is a completely new way of acquiring oocytes. The "newness" defines the word innovation. The management definition would consider only products that are successfully implemented into the market as innovation, even if they do not include new techniques but are new to the customer's needs [2].

Why is it so difficult for the scientist to understand the manager – and vice versa?

First of all, their motivations are different. Independence of science and knowledge creation is more important for the scientist than revenue-margins (that is true at least for university research). Second, many scientists see the manager as an "only money matters" person. And most scientists probably agree that money should be spent for research, although no immediate profit can be seen. And third, there is an arrogance on both sides, that each one thinks he understands the other one completely. This is maybe the most crucial point. The manager as well as the scientist would have to study at least parts of the other's field to understand not only the words, but also the other's motivations, thoughts and impact on value creation.

Therefore, firms need someone that can mediate between sciences and management – a manager who has profound knowledge of science, can motivate colleagues ("coaching") and handle financial responsibilities. "Especially now, as product life-cycles become ever shorter and resources for R&D have to meet higher expectations for profitability, we need multi-skilled entrepreneurs. Employees who have experience in both science and management," says Eggert Voscherau, President of CEFIC (the European Chemical Industry Council) from 2002 - 2004. That is, firms need a person who can cross the "Valley of Death" – the gap between existing research knowledge and commercialization [3].

All over the world, from the UK to Australia, new undergraduate studies that focus on science and business were established during recent years to bridge the communication deficit. There are also new graduate programs, e.g. the Cambridge-MIT Institute, the Stockholm School of Entrepreneurship or the International Graduate School of Chemistry in Muenster. In our opinion, even more work needs to be done.

In the scientific community, the need for multidisciplinarity, including business and ethics, is still not very present. On the contrary, many people in basic research might think that it is important to focus, at least for some years, on science alone. The latter is also shown by the fact that most scientists do not gain additional qualifications. Even worse, while business-people can gain masters degrees during their time in the industry and have certified courses, most scientific knowledge is not visible in a single curriculum. Compared to most managers, scientists also have a PhD or masters, but lack every additional feature.

These two facts--that most scientists lack management knowledge and that scientific qualifications are not transparent--lead to disadvantages in a scientist's management career.

Therefore, we propose two measures. First, we need a consistent advancement of university degrees and courses. This should be done in cooperation with companies, as they best know what the industry needs. Second, we must establish a system of certified scientific qualifications. Why should there only be "rhetoric training" but not an expert in "nano-technology" or "biotechnological production of amino acids"? Of course, this might also be accessible for managers who work in those fields. In any case, it would increase the transparency of scientific knowledge.

Both measures will help to fill the gap between the sciences and management. They will create a better understanding of R&D and management and hence help optimize processes within companies.

Thus, some scientists might become managers.

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[1] K. Hübner, H. Schöler et al, Derivation of Oocytes from Mouse Embryonic Stem Cells, *Science*, 2003, 300(5623), pp1251-1256

[2] E. Danneel, E.J. Kleinschmidt, *Journal of Product Innovation Management*, 2001, 18, pp 357-373

[3] Stephen K. Markham, Moving Technologies from Lab to Market, *Research-Technology Management*, Nov-Dec 2002, pp 31-42

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Research Paper

Condiment paprika research in Australia

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Abstract: Australian condiment paprika plant improvement research is 10 years old. The production and processing industry is in its infancy. The research is producing condiment paprika cultivars suitable for a highly mechanised crop husbandry system, with genes for early lignification of the stem, fruits for detachability of the calyx, high dry matter and pigment content. A potential hybrid seed production system is discussed.

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Introduction

Capsicum is one of the most versatile crops in cultivation. The fruit range from tiny very hot chillies and stocky pimentos through to long cayenne chillies and the giant 'Bell capsicums'. Both pungent and non-pungent variants are used as foods, spices, medicines and a source of pigments. In some countries capsicum is a national food used in many ways; raw, smoked, cooked, stuffed and as a salad and spice [1]. The condiment form is a highly valued spice and the extract of the spice, oleoresin, is used in the smallgoods and canning industries. More recently the cosmetic industry is making use of it as a source of natural pigment.

Several capsicum types are grown throughout Australia. Commercial production is on a market garden scale and is restricted to table capsicums for salads and cooking. Chillies and condiment paprika are mainly grown in domestic gardens by families of European and South American origin. Australia imports approximately $5 million worth of paprika products per year and these include milled paprika, flakes and dried unmilled paprika [2]. Recently some oleoresin was also imported for the food and cosmetic industries.

Although Australia has a 10 year-old research program in condiment paprika; commercial production is only just starting. The problem has been the relatively large amount of capital required to establish economically sound production. Without mechanised planting, harvesting and drying systems, the industry will not survive in Australia.

Hungary has produced very high quality condiment paprika (*Capsicum annuum* v. *annuum* Longum Group) unparalleled on the world market: its bouquet, taste and colour are supreme. Nevertheless, Hungarian paprika exports have declined significantly during the past years. This was partly due to heavy metal contamination caused by air pollution originating from the use of leaded petrol. Some unscrupulous companies were selling adulterated paprika that created bad publicity for the industry. The Hungarian authorities had to destroy approximately 25,000 tons of adulterated paprika and the paprika export industry declined significantly as a result. Exports to their traditional customers such as Czech Republic, Japan and Germany had nearly stopped ten years ago [2]. More recently, both local sales and exports of whole paprika and paprika products had to be stopped due to aflatoxin contamination. This was caused by dilution of the Hungarian product with paprika imported from South America [3, 4].

In 1994, the senior author received a private communication from a Hungarian wheat breeder colleague advising him of the problems that the Hungarian condiment paprika industry was facing. The senior author's response to his old colleague was that the problem, mainly referring to air pollution, could be easily solved by producing the famous Hungarian condiment paprika in Australia, in cooperation with the Hungarian researchers. Subsequently Dr. Norbert Somogyi,[1] at the time a research scientist with the Hungarian Vegetable Crop Research Institute Condiment Paprika Research Unit in Szeged, contacted the senior author for further discussions. He and his superiors liked the idea of producing the Hungarian condiment paprika in Australia. On 28th March 1996, a close collaboration was established between The Hungarian Vegetable Crop Research Institute, the Condiment Paprika Unit and the family company of the senior author, ASAS Pty Ltd. This authorised ASAS Pty Ltd to be the sole representative of the Paprika Unit in Australia and in the South Pacific region.

The Hungarians provided us with their most popular cultivars. These cultivars were included in a small-scale field trial at The University of Sydney, Plant Breeding Institute Cobbitty, NSW. This trial, our earlier experiments and the practical experience of many market gardeners demonstrated that *Capsicum* cultivars of Hungarian origin can be successfully produced on the Australian continent. However it became clear that condiment paprika could not be produced economically with the same crop husbandry methods as in Hungary and other condiment paprika producing countries where manual labour is comparatively inexpensive. The imported cultivars also expressed quite a degree of variability

[1] Now Agricultural Attaché at the Hungarian Embassy in France

due to genotype-environment interactions. For these reasons, it was decided to initiate a research program to find the most suitable crop husbandry systems and develop cultivars that were suitable for highly mechanised production techniques. To achieve these objectives a request was lodged to the Australian Government Rural Industries Research & Development Corporation (RIRDC) for research funding to assist the project.

Subsequently, research co-operation was established with The University of Sydney Plant Breeding Institute, ASAS Pty Ltd, The Hungarian Paprika Unit, Szeged, and the Rural Industries Research & Development Corporation.

I. The groundwork

ASAS Pty Limited was the applicant and later the grantee for the research project under the title "Condiment Paprika Breeding, Harvesting and Commercialisation". The aim of this project was to introduce and further develop genetic material of condiment paprika to produce cultivars with high initial pigment (>200 ASTA) and dry matter content (>18%) suitable for direct seeding and mechanical harvesting. Later aims were to develop a commercially viable integrated production, harvesting and processing system for identified markets.

Initial pilot tests strongly indicated that under Australian environmental conditions, Hungarian cultivars generate considerably higher pigment content in their fruits than in their country of origin. Whereas most of the Hungarian milled paprika on the world market is around 120-130 ASTA (American Spice Trade Association method 20.1) the same cultivars grown in Australia were producing on a semi commercial scale 180-250 ASTA in milled product. Table 1 shows some comparisons.

The first two samples were received by the senior author while visiting Hungary. The above figures clearly show large differences. The question may be asked why there are such big differences between the imported and the Australian grown milled product. The answer was simple in the case of samples collected from supermarkets in Australia. Importers were buying the cheapest available product.

Category/Cultivar	Origin/ Produce of	ASTA unit
Hungarian Csemege	Hungary/Hungary	120
Hungarian Extra	Hungary/Hungary	150
Imports:		
Retail sample 1	Europe/?	50
Retail sample 2	Europe/?	95
Retail sample 3	Europe/?	30
Retail sample 4	Europe/?	85
Retail sample 5	Europe/?	5
Retail sample 6	Europe/?	85
Retail sample 7	Europe/?	125
Szegedi 57-13	Hungary/ Australia	245
Szegedi 20	Hungary/Australia	220
Szegedi 80	Hungary/Australia	226
Kalocsai 50	Hungary/Australia	214

Table 1: Pigment levels in imported and locally produced paprika

The retail sample "5" may have been botanically derived from *Capsicum*, but was in fact a residue of milled product from which the oleoresin had been extracted! The quality of this imported product was inferior. Australians are not generally known to be paprika connoisseurs; only those immigrants familiar with better grades of milled paprika would know the difference and would wish to purchase a high quality product.

The differences between Hungarian and Australian grown paprika are not simple. We examined the crop husbandry methods used in both countries to ascertain whether Hungarian agronomic conditions may be more advantageous for paprika production. There is one obvious major difference between the environments of the two countries: namely the number of sunshine hours and sunshine intensity to which the crop is exposed during cultivation. Table 2 demonstrates the differences. Major paprika producing or potential producing regions are shown.

Region	**Growing Season**					**Total**
Hungary	**May**	**June**	**July**	**August**	**September**	
Szentes	260	270	300	270	190	1290
Szeged	244	251	273	274	195	1237
Pecs	251	257	299	265	177	1249
Tengelice	273	272	285	319	186	1335
Australia	**October**	**November**	**December**	**January**	**February**	
Wagga	267	318	314.	361.	290.	1552
Narrabri	290	343	324.	304.	294.	1556
Griffith	263	270	310	302.	273	1418

Table 2: Sunshine hours during growing season

The mean temperature in Hungary at Szentes and Szeged during the May-September growing season is 18.9°C and 19.6°C, respectively [5]; in Australia at Narrabri and Wagga the corresponding means are 23.1°C and 21°C (Aust. Bureau of Meteorology).

One of the most important goals was to find genotypes that could provide a base to create cultivars suitable for a mechanised farming system. Most capsicum genotypes have an indeterminate growth habit, with the plants flowering and bearing fruit continuously. Therefore, several harvests are needed to obtain a full yield. It is essential to find genotypes that allow a large part of the potential yield to be harvested in one operation. An obvious option was to look for variants with a determinate growth habit. A number of Hungarian cultivars have a determinate or semi-determinate habit. It was found that the cultivar Kalocsai 801 produced an acceptable yield and a large proportion of the fruit can be removed at the first harvest operation. This trait was utilised in our breeding program. To be able to use a mechanical harvester efficiently the plants must stand erect with a strong main stem. Most paprika cultivars have a relatively weak stem, and with a heavy production, the plants lodge easily. It is very difficult to harvest a lodged crop mechanically. It was paramount to find genes that ensure strong upright plants and if possible an early lignification of the stem. While a number of wild *Capsicum* species have a strong lignified stem, we found *Capsicum chacoense* had an early lignification of the stem, and fruit that were detachable from the calyx at ripening. This latter trait would be a great advantage for mechanical harvesting.

Finally, the paprika pigment quality should be discussed. Besides the taste and bouquet, colour is very important in all paprika products. Capsicum species contain unique carotenoids, eg. ketocarotenoids, capsanthin, capsorubin and cryptocapsin. The major contributors to the red colour of paprika are capsanthin and capsorubin, whereas the yellow-orange colour is from beta-carotene and violaxanthin [6]. Pigment content is usually expressed on a scale specified by the American Spice Trade Association (ASTA method 20.1). Extractable pigment, which measures total pigment content, is measured using a spectrophotometer and designated in ASTA units with higher numbers indicating brighter colour. We are determining the extractable colour in paprika by measuring the absorbency of an acetone extract by a spectrophotometer capable of accurately measuring absorbency at 460nm. Our results obtained this way are acceptable for breeding and the correlation between the BRI Australia Ltd, an accredited laboratory, results and our tests gave a correlation coefficient of r = 0.85.

Milled paprika and its extract, oleoresin, are used as a natural colouring source in a wide variety of foods, cosmetics and drugs. Oleoresin is extracted from milled paprika using organic solvents, eg. hexane, supercritical CO_2 and petroleum ether. When oleoresin is extracted from pungent capsicums or chillies it is called “Capsicum Oleoresin”. Besides the food industry it is mainly used by security organisations for crowd control. When the oleoresin is extracted from non-pungent paprika it is labelled as “Paprika Oleoresin”. The extracted “Paprika Oleoresin” has a concentrated flavour and aroma of the original milled product. It can be diluted according to the end use requirements. The great advantages of the oleoresin over the original milled product are [7]

- It is free from pathogens and microbiological infections; it is a sterile extract
- It is a clean product; it is free of physical contaminants
- The concentrate can be easily distributed in media such as oil or water
- The concentrate has a longer shelf life than the milled product and is free from deterioration caused by pests or moulds.

Because oleoresin has such a large advantage over the traditional milled product it was decided that for Australia we should concentrate on creating cultivars with high pigment content and the ability to produce high pigment yield per unit area.

Farmers want plants that establish quickly, with the highest possible yield, free of diseases and high ent. One of the options to achieve these aims is the utilisation of hybrid vigour using hybrid seed. Hybrid seed of paprika is extremely expensive because it is produced by manual labour. Private seed companies produce hybrid seed worldwide in locations mainly determined by the availability of cheap labour and good growing conditions.

II. Agronomic considerations

During the 1997/98 season, selected cultivars from Hungary and USA were tested at two field sites. One was at the Plant Breeding Institute Cobbitty, 65 km southwest of Sydney; the other was at Merriwa, 325 km northwest of Sydney. The area at Cobbitty used for the trial was an alluvial clay soil with pH 7.2, while the site at Merriwa was light sand with pH 6.4. The aim of this pilot trial was to see how the introductions behaved under Australian environmental conditions. In all field trials, randomised complete block designs with four blocks were used [8].

Nearly all introductions showed variability due to genotype-environment interaction; this was particularly evident in the Hungarian cultivars. As we intended to base our paprika production on the high quality of the Hungarian paprika we decided to reselect the Hungarian cultivars that showed a high degree of variability. The Cobbitty trial was subjected to a simple weighted analysis to be able to find the types that best suited our aims. The results of this trial are shown in Table 3.

In this weighted evaluation, pungency was considered a negative value as our goal was to have non-pungent paprika production. The Hungarian introductions performed satisfactorily but were difficult to harvest mechanically because of their relatively weak stems, uneven ripening, and, in some cases, the difficulty in breaking the pedicel away from the stem.

Cultivar	Yield 0.5x	ASTA 1x	Taste 10x	Appearance 10x	Capsaicin -(5x)	Value	Rank
Szegedi 80	104	272	77	85		538	2
Kalocsai 90	97	166	81	84		428	9
Szegedi 178	108	193	70	88	6300	-5841	15
Szegedi 179	110	232	70	88	3675	-3175	14
Szegedi 20	120	270	75	90		555	1
Szegedi 57-13	89	195	75	95		454	7
Szegedi 17	100	222	67	83		472	5
Szentesi NFD	111	210	83	93		497	3
US Hybrid	210	298	70	90	400	268	11
Papri King	148	242	70	88	200	350	10
Papri Mild	152	225	78	92	50	497	3
Papri Queen	141	232	70	86	300	229	12
Kalocsai 50	117	195	76	92		480	4
Szegedi F-03	75	248	70	88	3500	-3019	13
Kalocsai E-15	99	178	69	83		429	8
Kalocsai 801	117	181	83	80		461	6

Table 3: Weighted Analysis of 1997/98 Paprika Cultivar Trial

At Merriwa, we also had a sowing depth trial to determine the optimum depth of sowing on lighter soil where direct seeding could be justified. A 15 mm sowing depth was significantly better than 45 mm, and neither was significantly different from the 30 mm depth (Table 4).

Depth mm	Mean yield	Homogeneous groups
15	31.00	**a**
30	22.375	**a,b**
45	13.708	**b**

Table 4: Effect of sowing depth on yield

This result confirmed the Hungarian and the New Mexican recommendations on depth of sowing, and also emphasized the importance of soil types and moisture conditions. The extension workers of New Mexico strongly recommended covering the row with a 7-10 cm 'cap' which is removed with a dragging harrow before the seedlings emerge (crook stage) [9]. This method reduces the drying out of the seedbed. Post sowing watering can cause problems and should be avoided.

Four sowing times were combined with the depth of sowing in 15-day intervals starting on 1st October 1997. The results again supported overseas advice showing that the second sowing, mid-October, was the optimum sowing time. Obviously, the soil temperature must have been above the optimum level of around 15°C. At the third sowing time the seed emergence was significantly lower than at the second, but still acceptable. Both the first and fourth sowings gave significantly lower yields than the second and third sowings. They were not different from each other (Table 5).

The most favourable sowing time at Merriwa was in the second half of October in 1997 with a sowing depth between 15 mm and 30 mm depending on soil type.

Our practical experience and the experimental data indicated that the Hungarian and New Mexican crop husbandry practices could be adopted in Australia. However, plant improvement had to be given wide-ranging attention.

Sowing time	Mean yield	Homogeneous groups
1st Oct.	3.6667	**c**
15th Oct.	49.389	**a**
1st November	30.056	**b**
15th November	6.333	**c**

Table 5: Influence of sowing time to yield

III. Genetic improvement of paprika

In order to develop paprika cultivars suitable for Australian climatic conditions and utilising a highly mechanised production system, we had to consider among other factors, high germination energy, a strong upright stem, fruit setting well above the ground, synchronised flowering together with a semi-determinate growth habit, snap-off pedicel with detachable calyx, fruits with high dry matter (18% +), very high pigment content (ASTA 200+), high yield and disease resistance. The paprika cultivar development was based mainly on the classical pedigree method, and to save time and space, it was combined with single seed descent (SSD; Fig. 1) [10]. The SSD method is widely applied in cereal breeding programs [11,12] and the senior author successfully used it earlier in wheat and ornamental *Capsicum* improvement work. With this system, two or three generations could be advanced in one year. We are using negative and positive selections while using the SSD method as it is shown in Figure 2.

In overseas condiment paprika breeding programs, the mechanisation requirements were neglected; therefore we had to build completely new plant types. The foundation was available in reasonably high quality Hungarian cultivars; nevertheless, they were not suitable for a mechanised production system and their pigment contents could be further improved. The foundation material consisted of introduced cultivars and ecotypes from Hungary and Spain, cultivars and wild species from the USA and South America, and materials from the germ plasm collection of the defunct Queensland capsicum breeding program.

Figure 1: F_4 SSD plants in the greenhouse

Parent A X Parent B

↓

F_1 generation

↓↓ ↓↓ ↓ ↓↓ ↓↓

F_2 generation

200 seeds are planted in punnets and grown in greenhouse

No selection applied

↓↓ ↓↓ ↓ ↓↓ ↓↓

F_3 generation

Selection against non-longum phenotypes and pungent fruits

Selection for plants with fruits over200 ASTA.

↓↓ ↓↓ ↓ ↓↓ ↓↓

F_4

Selection as in F_3

↓↓ ↓↓ ↓ ↓↓ ↓↓

F_5

Selection as in F_3.

↓↓ ↓↓ ↓ ↓↓ ↓↓

F_6

and further generations

Grown in the field for further selection and evaluation

Figure 2: SSD method schematic illustration

The collection was tested to find the appropriate traits to help build the new type of paprika. Most of the traits that we needed were represented in the collection, not in one given genotype but dispersed over several varieties and wild species. Therefore, we had to establish an ongoing crossing program to combine the appropriate genes into an acceptable breeding population. A number of interspecific crosses were required as well. Although most of the interspecific combinations were impossible to achieve according to the literature, we found a way to establish such combinations. Some of them needed several years to accomplish (e.g. detachability came from a wild species).

Some American cultivars displayed high yield potential and satisfactory pigment content. However, as they had variable levels of capsaicin content, low dry matter and inferior taste they were not suitable for the production of the Hungarian type of paprika. They were used as parents in the crossing program to improve the performance of the Hungarian paprikas. Special breeding lines were also created to increase the numbers of fruits produced per plant.

The interspecific combinations being used involved *Capsicum chacoense, C. chinense, C. baccatum* and various other *C. annuum* cultivars to achieve lignifications of the stem, and fruit detachability from the calyx (Fig. 3).

The program concentrated on backcrossing to maintain the Hungarian paprika's quality traits with an improved yield but with easy detachability of the fruit from the calyx. According to the literature easy detachability of the calyx is associated with excess softening of the fruit at maturity [13]. The program used intermating of interspecific hybrids to find recombinants that were easily detached from the calyx (Fig. 3) while the ripe fruit remained firm. The earlier indication that these two characteristics are determined by common genes is incorrect; they are closely linked [14] and with appropriate selection can be separated. *Capsicum chacoense* crosses, to achieve detachability, were successful, but the F_1 plants were sterile males and to obtain seed from them, they had to be pollinated with a fertile male cultivar. The unrestrained detachment of the fruit from the calyx was found to be a simply inherited incompletely dominant characteristic as it was reported [15].

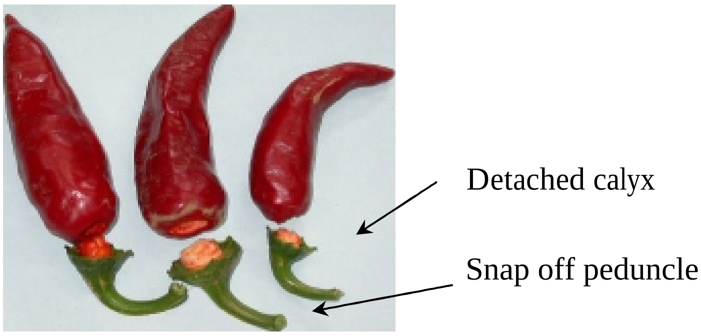

Figure 3: Paprika fruits with the detachability gene

IV. The current selection program

Selection is conducted partly in the field and partly in the laboratory; in the field for phenotypic characteristics, and in the laboratory for dry matter and pigment content. Selection is repeated until the progenies show uniformity, usually in the seventh to tenth generations after the last cross. When some of the advanced lines are sufficiently uniform they are subjected to a rigorous program of at least three years of field testing, starting with three row plots and finishing with twelve row plots. When the performance of a line is acceptable, it is submitted for variety protection (PBR). This is followed by large-scale regional field tests on commercial properties and industrial tests before commercial release.

V. Outcomes:

During 2004 we submitted three selections for plant variety protection (PBR), namely "Sunired", "Earlysuni" and "Cerise Sweet". The first two cultivars are reselections from introduced cultivars, which showed variability where first grown in Australia. "Cerise Sweet" originated from old Hungarian breeding material of the senior author**;** **"**Sunired" produced 89% of its total yield in the first harvest, and is therefore a good candidate for mechanical harvesting; "Earlisuni" is fast maturing with good dry matter and pigment content; "Cerise Sweet" (Fig. 4) is a constantly high dry matter and pigment (over 280 ASTA) producer. In our experiments, "Cerise Sweet" gave the highest pigment production per unit area. Due to the selection process all three cultivars have the 'snap off' gene that allows an easy separation of the pedicel from the stem.

Figure 4: Seed production field of "Cerise Sweet" at west of Sydney. This crop produced fruits with 328 ASTA

Fifty of our advanced lines are entering in our first year Variety and Strain trials. Their mean ASTA value is 310, all have the 'snap off" gene and 41 lines have the "detachability" trait, which allows the calyx to be removed from the fruit and simultaneously have the early lignification of the stem.

F_6-F_7 lines have an average 274 ASTA while the F_5 selections mean ASTA is 266. Our segregating populations progress with limited selection by way of SSD to F_5 (Fig. 2). We predict that in the near future, we will have cultivars on the market that have high pigment and dry matter content together with suitability for highly mechanised production systems.

VI. Capsicum Hybrid Seed

Research underway is attempting to produce condiment paprika hybrid seed in an economically acceptable price bracket. Currently hybrid paprika seed is sold by seed number, not by weight. As a consequence one kilogram of paprika hybrid seed can cost up to US$25,000 [16, 17, 18].

Capsicum is a facultative open-pollinated crop in Australia due to the activity of native bees, but is a facultative self-pollinated crop in Europe. Honeybees are not attracted to *Capsicum* because the nectar content in the flowers is low [19]. As a consequence, in Europe, 300 metres [20] is the compulsory separation distance for two cultivars of seed production; in contrast in Australia we may need 2-3 km or even greater distances due to the activity of the native bees.

It is important to reduce the cost of hybrid seed. We thus seek to use a designed system of sterile male paprika lines where the identification of sterile male plants is easy, and can be determined in the seedling stage. The selected sterile male plants can be propagated by micro-propagation or as cuttings. These male sterile plants would be planted in the field together with the pollen source and pollination would take place by native bees.

The improvement programs are based mainly on exploiting natural sources of germplasm by means of selection and hybridisation. Heterosis breeding has received considerable attention in crop production. The heterosis effect in capsicum manifests itself in higher early (yield at first harvest) and total yields, improved chemical composition, as well as other morphological features of the fruits [21, 22, 23, 24]. There is also significant heterosis for seed production in C*apsicum* hybrids made by using male sterile systems [25, 26].

In male sterile *Capsicum* plants versus fertile ones (Figure 5), the anthers are absent or shrunken, and contain either no pollen or only a small amount of viable pollen.

As in may other species; there are two different types of male sterility in *Capsicum*, genetic and cytoplasmic. Genetic male sterility is conferred by nuclear genes inhibiting the normal development of anthers and pollen, usually single recessive (*ms*) factors. Cytoplasmic male sterility is determined by mutant genes in cytoplasmic organelles, and is transferred only through the egg. The action of cytoplasmic genes for male sterility may be modified by the action of fertility restoring genes [27] in the nucleus: it is the interactive system that is exploited in hybrid production in many crops.

Figure 5: Male sterile (a) and male fertile (b) paprika flowe

A wide range of methods have produced male sterility in *Capsicum*. The most widely used treatment for induction of male sterility is ionising radiation, such as gamma- or X-rays. There have been several investigations [28, 29, 30, 31, 32] to determine the optimal conditions for mutagenesis by chemical agents. Chemically induced male sterility mutants were incomplete in many cases, climate dependent, and invariably accompanied by unfavourable effects on the development of plants, and also caused high ovular sterility. Gametocides can induce a temporary male sterility in several crops, including *Capsicum* [33, 34]. The use of a gametocide requires uniform plants in the same developmental stage. Weather events can influence the timing of application and the effect of gametocides at the optimal treatment stage. There is also the added problem of gaining a licence for the use of gametocides.

Interspecific hybrids between species of *Capsicum* can be made with varying degrees of success [1]. The hybrids can be sterile in paprika due to chromosomal or plasmon-genome incompatibility [35]. There are several known male sterile lines used in research programs. These differ from each other in agronomic characters, growing time, combining ability, plant growth habit and fruit type. They carry various male sterility genes [36].

Type	Name / identification	Possible gene / genotype	Origin
Genetic male steriles	HM2	*ms2*	Hungary
	HM3	*ms3*	Hungary
	HM5	*ms5*	Hungary
	#5093	Segregates to *msms*	Israel
	#5102	Segregates to *msms*	Israel
Cytoplasmic male steriles	Peterson cms	*Srfrf*	USA
	MSA	*Srfrf*	Korea
	#5071	*Nrfrf*	Israel
	#5076	*NRfrf*	Israel
	#5077	*NRfRf*	Israel
	#5202	*NRfRf*	Israel
	#5195	*Srfrf*	Israel
	#16466	*Srfrf*	Israel
	#16167	Segregates to *SRfrf*, *Srfrf*	Israel
	#16168	Segregates to *SRfrf*, *Srfrf*	Israel

Table 6: Type and range of male sterile lines used in the breeding program

To generate male sterility in condiment paprika we collected known male sterile *Capsicum* lines from around the world. This collection consisted of cytoplasmic and genetic sterile male lines (Table 6). We backcrossed these lines into condiment paprika and during the selection program we established sterile male lines of paprika.

Gamma irradiation of seeds was also used to generate male sterility in the Longum group type of C*apsicums*. Seeds were soaked in distilled water for 0, 48 and 96 hours prior to irradiation at 3, 5, 7, 9, 12, and 15 Krads. Seeds, soaked for 0, 48 and 96 hours, not exposed to radiation were used as controls. Controls did not produce male sterile plants. The overall frequency of male sterility among the irradiated materials was 0.3% (Table 7). The percentage of sterile male plants increased with increasing radiation dose. Induction of male sterility was more successful with increasing soaking periods. The mutants were incorporated into our breeding program.

Plant material was grown in flying insect proof isolation tunnel houses. Certain phenotypic/physiological characteristics, e.g. shrunken anthers of male sterile flowers, plant height and flowering time were found to be markers for male sterility though male sterility can only be detected at the flowering phase. Our aim is to select sterile male plants at the seedling stage, so that only sterile male plants would be planted into the field along with the pollen source. The production field would show a uniform pattern (number of male sterile rows alternating with a certain number of rows of pollen source) ensuring the efficient usage of available land and other resources.

In order to identify a genotype with a unique trait that cannot be observed at a particular growth stage, 'markers' can be used. These can be phenotypic or molecular. Since no phenotypic markers for male sterility were apparent at seedling stage we decided to use the Amplified Fragment Length Polymorphism® (AFLP) method to find molecular markers linked to the *ms3* male sterility gene, which is widely used in our and other research/breeding programs. We have one candidate primer combination [37], which potentially allows us to select for male sterility at the seedling stage (Fig. 6). The validation of this possible marker is underway.

Sterile male plants can be propagated with the help of micro-propagation [38, 39] or as cuttings [40]. Different explant types can be used to propagate sterile male lines *in vitro*. Several media have been tested, and that with the highest multiplication rate will be used for propagation. Cutting-derived young plants are produced in the greenhouse (Table 8) and then tested under field conditions to compare to seed derived seedlings.

Treatment (Krd/hours of soaking)	**Male sterile plants (%)**	**Treatment (Krd/hours of soaking)**	**Male sterile plants (%)**	**Treatment (Krd/hours of soaking)**	**Male sterile plants (%)**
3/0	0.25	3/48	1	3/96	0.5
5/0	0	5/48	0.125	5/96	0.25
7/0	0.125	7/48	0.125	7/96	0.75
9/0	0.375	9/48	0.25	9/96	0.5
		12/48	0.125	12/96	0.75
		15/48	0	15/96	0.5
Treatment frequency	0.19		0.27		0.54
Overall frequency	0.3				

Table 7: Male sterile mutations found in irradiated *Capsicum* seeds

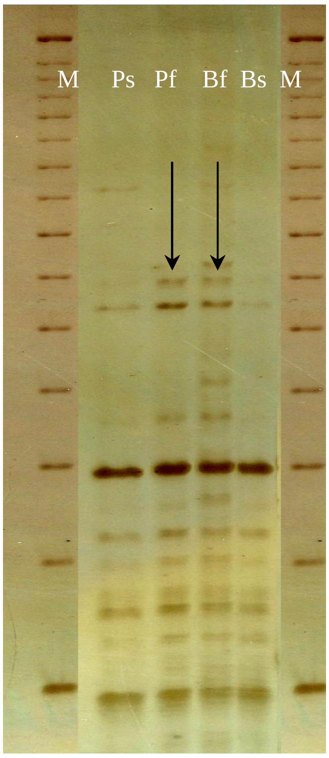

Figure 6: AFLP DNA fingerprints of sterile and fertile parents and bulks of the 2-primer combination which produced polymorphism. Arrows indicate the polymorphic bands, present in the fertile parent and progenies of fertile bulks. M - 25bp ladder, Ps - Sterile Parent, Pf - Fertile Parent, Bf - Fertile Bulk, Bs - Sterile Bulk, M - 25bp ladder.

It is planned that male sterile plants will be planted with a pollen source, with pollination taking place by insects, mainly native bees (genera *Trigona*, *Austroplebeia*, *Xylocopa*, and *Amegilla*) [41]. These sting-less native bees are found across Australia and are known to be good crop pollinators even for Solanaceae, where 'buzz' pollination is required [42].

Male sterile line	Rooting (%)
HM2	95
HM3	96
HM5	95
Peterson cms	83
MSA	86

Table 8: Rooting percentage of cuttings derived from male sterile lines

During field trials a cost benefit study will be carried out to determine the economics of hybrid paprika seed production in Australia using this system. This will enable us to determine the most efficient method of large-scale hybrid paprika seed production within a reasonable price bracket.

VII. Conclusion

We believe that by applying this system we should be able to produce paprika hybrid seed in an economically acceptable price bracket. If so, the "product" would be marketable worldwide because of the increasing demand for paprika as a spice and natural colouring agent. This could open up a new avenue for the Australian industry as an exporter of paprika products and hybrid seed of our improved cultivars that are both fit for highly mechanised production and have a high pigment and dry matter content.

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References

[1] Bosland, P.W., Votava, E.J. (2000) Peppers: Vegetable and Spice Capsicums. CABI publishing, pp 204

[2] Derera N.F. (2000) Condiment Paprika Breeding, Harvesting and Commercialisation. RIRDC publication, No 00/155, pp 44

[3] Magyar Nemzet (2004) Paprika bomba robbant [Paprika bomb exploded] News report at 29 October 2004

[4] Magyar Nemzet (2004) Gazdasag, Miniszter tudott az importrol [Minister knew about the import] News report at 30 October 2004

[5] Derera, N.F. (1951) A honositasi kutato munka elmelete, hazai eredmenyei. Magyar Tudomanyos Akademia 1951. evi Nagygyules eloadasi [The theory and research of acclimatization work in Hungary, *Hungarian Academia Science Proc.*], pp 325-336

[6] Reves, M.J. (1987) Re-evaluation of Capsicum color data, *J. Food Sci*. 52, pp 1047-1049

[7] http://www.kancorflavours.com

[8] Balaam, L.N. (1972) The Randomized Complete Block Design Fundamentals of Biometry. The Science of Biology Series No. 3, George Allen & Unwin Ltd.

[9] Bosland, P.W., Bailey, A.L., Cotter, D.J. (1994) Growing chilies in New Mexico. NMSU, Cooperative Extension Service Guide H-230

[10] Om, Y.H., Choi, K.S., Lee, C.H. (1984) Comparison of three breeding methods in pepper, *J. Korean Soc. Hort. Sci*. 25, pp 251-255

[11] Knott, D.R., Kumar, J. (1975) Comparison of early generation yield testing and a single seed descent procedure in wheat breeding, *Crop Sci.* 15, pp 295-299

[12] Tee, T.S., Qualset, C.O. (1975) Bulk populations in wheat breeding: comparison of single-seed descent and random bulk methods, *Euphytica* 24, pp 393-405

[13] Smith, P.G. (1951) deciduous ripe fruit character in peppers, *Proc. Amer. Soc. Hort. Sci.* 57, pp 343-344

[14] Kormos, J., Kormos, J. (1957) Soft green pepper. Novenytermeles [Crop production] 6, pp 33-44

[15] Spascoevic, V. (1976) Easily separation of the pepper fruit its calyx and importance of this characteristic for mechanization of harvesting and for improvement of biological value of the fruit. Poljopriveda 23, pp 27-31

[16] Berke, T.G. (1999) Hybrid seed production in Capsicum, *J. New Seed*, 1:3/4, pp 49-67

[17] Derera N.F. (2000) Recent Developments in Condiment Paprika Breeding, *Agrifood 2000 Research Proceedings*, pp7-12

[18] Pek, M. (1999) Estimation of Red Pepper hybrid combinations, In: *Kertgazdasag [Horticultural]* 31(3), pp 102

[19] Derera N.F. (2000) Condiment paprika – a potential new crop, *Agricultural Science* 1, pp 24-27

[20] Hungarian Seed Act MSZ 7145/1999; CXXXI 1996/3/19

[21] Mamedov, M.I., Pyshnaja, O.N. (2001) Heterosis and correlation studies for earliness, fruit yield and some economic characteristics in sweet pepper, *Capsicum and Eggplant Newsletter* 20, pp 42-52

[22] Nayaki, D.A., Natarajan, S. (2000) Studies on heterosis for growth, flowering, fruit characters and yield in chilli (*Capsicum annuum* L.), *South Indian Horticulture*, 48:1/6, pp 53-55

[23] Daskalov H., Russinova I., Popova D. (1967) New hybrids and constant varieties of pepper, *Hortic Vitic Sci Sofia* 4, pp 63-71

[24] Pearson, O.H. (1983) Heterosis in vegetable crops. In: Frankel R. (ed) Heterosis: reappraisal of theory and practice. Monographs Theoretical Applied Genetics vol.6 Springer, Berlin, Heidelberg New York, pp 171-175.

[25] Meshram, L.D., Ghongade, R.A. (1995) Performance of male sterile based hybrids in chilli (*Capsicum annuum* L.), *Agricultural Science Digest*, 15:1/2, pp 31-34

[26] Prakash, N.S., Lakshimi, N., Harini, I. (1987) Male sterility and manipulation of yield in capsicum, *Capsicum Newsletter* 6, pp 35

[27] Peterson, P. (1958) Cytoplasmically inherited male sterility in Capsicum, *Am. Nat.* 92, pp 111-119

[28] Daskalov S. (1968) A Male Sterile Pepper (*C. annuum* L.) Mutant. TAG 38, pp 370-372

[29] Joshi, M.M., Khalatkar, A.S. (1981) Experimental mutagenesis in *Capsicum annuum*: I.Effect of different doses of gamma radiations on capsule and seed production, *Acta Hort.* 111, pp 55-61

[30] Bhargava, Y.R., Umalkar, G.V. (1989) Productive mutations induced in *Capsicum annuum* by physical and chemical mutagens. Acta Hort. 253, pp 233-238

[31] Bansal, H.C. (1972) Induced mutation affecting flower development in Capsicum annuum L, *Current Sci*., 42, pp 139-140

[32] Alcantara, T.P., Bosland, P.W., Smith, D.W. (1996) Ethyl Methanesulfonate-Induced Seed Mutagenesis of Capsicum annuum, *Heredity* 87, pp 239-241

[33] Walkof, C. (1959) A selective gametocide for tomato. *Tomato Genetics Cooperative* 9

[34] Daskalov, S. (1998) *Capsicum. In: Hybrid Cultivar Developmen*t, S.S. Banga and S.K. Banga (Eds) Narosa Publishing House, New Delhi, India, pp 498-511

[35] Shifriss, C. (1997) Male sterility in pepper (Capsicum annuum L.), *Euphytica* 93, pp 83-88

[36] Daskalov, S., Poulos J.M. (1994) Updated Capsicum Gene List, *Capsicum and Eggplant Newsletter* 13, pp 15-26

[37] Nagy, N., Derera, N.F., Sharp, P.J. (2004) *Capsicum*: Cost Effective Hybrid Seed Production. Proc. 22^{th} Meeting on Genetics and Breeding of Capsicum and Eggplant, pp 89

[38] Gunay, A.L., Rao, P.S. (1978) In vitro plant regeneration from hypocotyl and cotyledon explants of red pepper, *Plant Science* 11, pp 365-372

[39] Phillips, G.C., Hubstenberger, J.F. (1985) Organogenesis in pepper tissue cultures, *Plant Cell, Tissue and Organ Culture* 4, pp 261-269

[40] Sultanbawa, F., Phatak, S.C. (1991) Propagation of Sterile Ornamental Pepper by Cuttings and in vitro Shoot-tip Culture, *HortScience* 26, pp 1078

[41] http://www.zeta.org.au/~anbrc/beesinyoura rea.html

[42] Raw, A. (2000) Foraging behaviour of wild bees at hot pepper flowers (Capsicum annuum) and its possible influence on cross pollination, *Ann. Bot.* 85, pp 487-492

Research Paper

Chemicals Regulation and the Porter Hypothesis
A Critical Review of the New European Chemicals Regulation

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Abstract: In this contribution, discussions about the Porter Hypothesis and the pros and cons of the new European chemicals regulation system REACH are tied together. The contribution seeks to apply the Porter Hypothesis to the field of European chemicals regulation. Porter's claim of positive effects of regulation on innovations seems especially important for the chemicals sector pursuing differentiation. But, understanding Porter's concept of strategic management indicates that certain segments of the chemicals industry will suffer negative effects on competition and innovation.

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Introduction

Environmental policy is increasingly coming to the fore among the multitude of factors affecting the corporate competitive environment. The literature theoretically and empirically reveals a divided relationship between environmental policy, competitiveness and innovation [1, 2]. In the traditional view, strong competition and high innovation go hand in hand, as long as product markets are not impeded by state environmental regulations. By contrast, Ashford and Heaten [3], and Ashford, Ayers and Stone [4] empirically demonstrate that a positive link existed between environmental legislation and environmental innovations back in the 1970s. The idea of competition being improved by environmental legislation has since usually come to be associated with studies by the MIT-economist Michael E. Porter. The essence of the 'Porter Hypothesis' is that strict environmental regulations can induce efficiency and encourage innovations that help improve competitiveness.

The draft of the European Commission on the future chemicals regulation has triggered a controversial debate about its economic consequences. Although the need for reform is accepted by the European Commission, national authorities and the chemicals industry has been extremely critical of the anticipated economic impacts. Criticism is largely directed against the claimed resulting decline in competitiveness and innovation [5, 6, 7]. Moreover, the proposed regulations extend far beyond the sector of the chemicals industry and affect many related industrial sectors. This opinion is disputed by Experts of the German Advisory Council on the Environment [8], which believes that by bringing about safe, environmentally sustainable products, the new legislation holds and encourages competitive advantages and opportunities for innovation.

In this contribution, the discussion about the Porter Hypothesis and the pros and cons of the new European chemicals regulation are tied together. The contribution seeks to apply the Porter Hypothesis to the field of European chemicals regulation. In addition, it addresses the question of whether the Porter Hypothesis holds in this field. Section I explains the strategy for corporate management referred by Michael E. Porter and the Porter Hypothesis. Section II analyzes the characteristic features of the chemicals sector and the new European chemicals regulation. The following section III evaluates the strength of the hypothesis by examining various regulative aspects of the new chemicals legislation. Section IV gives a summary and some final observations.

I. The strategic management concept according to Michael E. Porter and the Porter Hypothesis

Porter's strategic management concept and innovation strategies

The 'Diamant Framework' in the strategic management concept. The basic idea that the positive effects of environmental policy encourage competitiveness and innovation is attributed to a model of strategic corporate management. In his so-called »Diamond Framework« Porter summarises the relevant competition factors [9]. The model is developed on the basis of (i) company strategy, competition structure and rivalry, (ii) factor conditions, (iii) demand conditions and (iv) related and supporting industries as four determining and (v) chance and (vi) government as two additional factors. In his analysis, Porter focuses on productivity, regarding it as the most important source of economic success [10].

In the »Diamond Framework«, the most important factors influencing innovations are the conditions determining the character and degree of competition and the structure of the industry concerned. The structure and the type of competition result in certain business strategies, which are also responsible for the types of innovations (product vs. processes innovations) pursued. Innovations are in turn the key to achieving and maintaining competitive advantages – in other words, they are the basis of economic success. Accordingly, dynamic competition and innovations are correlated.

From the »Diamond Framework«, Porter develops 'five forces of competition' whose interaction determines the intensity of competition and the profitability of an industry (cf. Fig. 1).

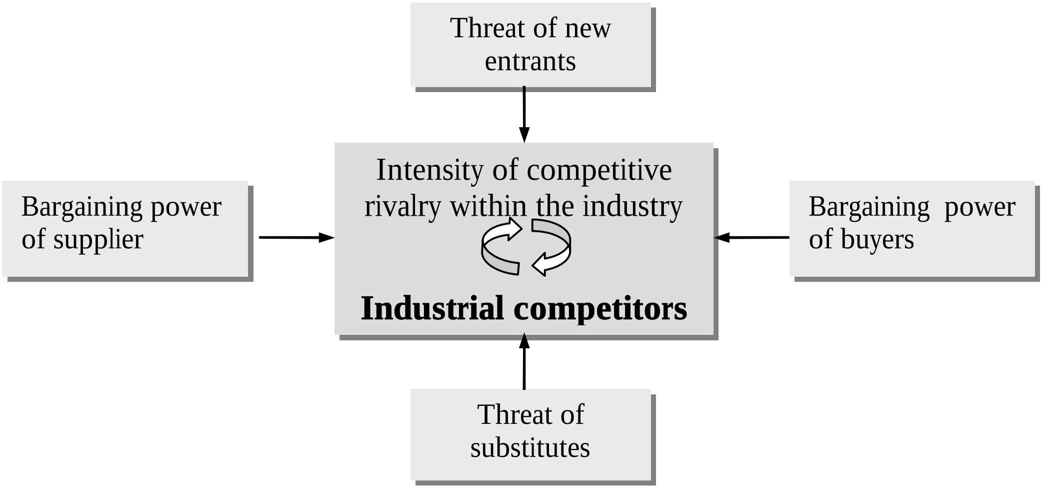

Figure 1: The five factors or forces affecting competition in an industry [11]

The role of environmental regulations within the stimulation of innovation solely consists in influencing the forces of competition: "Regulation creates a new competitive environment." [3]. Hence, although regulation can *increase* the chances of gaining a competitive advantage by means of innovation, it cannot *create* this advantage.

Competition advantages and innovation strategies

The strategic concepts of cost leadership and differentiation. Porter derives two fundamental types of strategic advantages from the »Diamond Framework«: low costs and differentiation (see Fig. 2). Gearing corporate strategy to cost leadership or differentiation affects not only technology and market strategies, but also the composition of the product portfolio.

The aim of cost leadership is to gain a 'cost advantage' over the competition, especially in markets characterised by mass products and price competition. The basis of a competitive cost structure comprises low costs for raw materials and energy, efficient production technologies and locational advantages. Other important requirements for cost leadership are size-related economies of scale based on large market shares, learning effects and a maximum level of production capacity utilisation [12].

Cost advantages mostly arise in the areas of material resource inputs and the technological production process. Since competitive advantages from cost leadership are tied up in cost minimizing strategies, the focus on innovations is primarily on enhanced production technologies and process innovations.

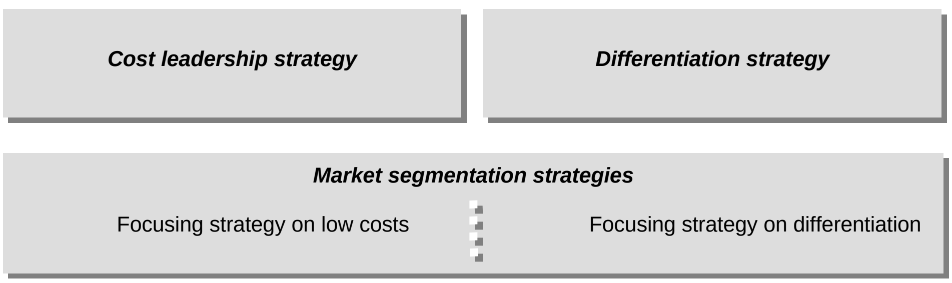

Figure 2: Porter's generic competition strategies [11]

Pursuing the differentiation strategy means attributing key importance to opening up and shaping new areas of market segments, as well as expanding and integrating the spectrum of products and their characteristics. Successful differentiation relies on product innovations which require an at least temporary monopoly position. The monopoly profit is not derived from economies of scale, but rather from having a 'knowledge advantage' over the competition, as well as from proximity to customers. Differentiation in quality competition means being able to create and offer new specific characteristics for products which allow a price policy that overcompensates for the additional costs of differentiation, and whose highly specific nature and comparatively high capital requirements act as an entry barrier to competitors [12]. An important factor of successful differentiation is the ability to react flexibly and rapidly to market demands. These characteristics are usually possessed by small and mid-sized enterprises (SMEs) that can in turn gain differentiation advantages.

According to Porter's strategy concept, the simultaneous combination of cost leadership and differentiation in a single market segment is not recommended, for being "stuck in the middle" entails a high entrepreneurial risk coupled with a low return on investment [11]. However, in a process of successive progression, the advantages of both strategies can be utilized [12]: starting from a differentiation strategy, sufficient market growth enables economies of scale to be achieved, which in connection with high market shares and learning curves result in cost advantages. On the other hand, as far as mass products are concerned, product life cycles are typically advanced and cost advantages are yet to be achieved. Transition to differentiation entails the adaptation or creation of new competence and expertise, which is a harder process altogether.

The Porter Hypothesis

Innovation effects and first-mover advantages of environmental regulation: the Porter Hypothesis. Based on a growing density of environmental regulations in the industrialised countries, the impact of environmental policies on competition and innovation is the subject of controversial discussion. The Porter Hypothesis expressly emphasises the possibility of a link between environmental objectives and competitive advantages by means of innovation. The performance properties of the competitive forces are altered by legislation; innovations provide a way of compensating for these changes. Porter expounds that environmental regulations can improve the chances of gaining competitive advantages while simultaneously environmental objectives can be effectively pursued ('win-win strategy'). According to Porter, regulation can lead to positive effects for competition; these "can not only lower the net costs of meeting environmental regulations, but can even lead to absolute advantages over firms in foreign countries not subject to similar regulations." [13] The opportunities for competitive advantages derive from the following implications [14]: (i) regulation may have a signalling effect revealing inefficiencies of the resource management and technological improvements; (ii) information has the character of a public good, i.e. the provision or demand for information by legislation can raise corporate awareness; (iii) regulation may reduce the uncertainty of investing in certain innovations and hence lessen the risks of new technology; and finally (iv), regulation may lead to internal barriers within companies being overcome.

Porter identifies two different effects in which the objectives of environmental improvements and enhanced competitiveness can be combined in a win-win situation [13]: firstly, meeting a more stringent environmental regulation leads directly to competitive advantages for companies through the need for innovations ('innovation effect'); secondly, companies achieve a technological advantage over the international competition leading to 'first mover advantages'.

- *Innovation effect:* A strict environmental regulation triggers the discovery and introduction of cleaner technologies and environmental improvements, making production processes and products more efficient in terms of resource productivity. As well as affecting the economy as a whole, these competitive advantages also result in benefits for individual companies. Porter estimates that in many cases, the cost savings that can be achieved are sufficient to overcompensate for both the compliance costs directly attributed to new regulations and the innovation costs. The compensation or even overcompensation for innovation costs solely by the innovation effect (known as 'innovation offsets') is referred to as the 'free lunch hypotheses'.

- *First-mover advantage:* Competitive advantages are linked to the rising environmental awareness observed throughout the world – but they can only emerge to the extent that national environmental standards anticipate and are consistent with international trends in environmental protection. Competitive advantages will arise for corporations under the regulation in this region as soon as international policy diffusion occurs. This 'first mover advantage' comprises using innovative technologies for the first time which, owing to learning curve effects or patenting, attain a dominating competitive position. At the macroeconomic level, a first mover position can also prove efficient if the competitive disadvantages of the polluting industry are compensated (or overcompensated) by first mover advantages of the environmental protection industry.

The innovation effect and the first mover advantages are two mechanisms in which regulation can alter the forces of competition, and bring about beneficial effects for competition. Regarding the perception of competitive advantages, Porter believes in the efficiency and effectiveness with which companies use essential resources: "At the level of resource productivity, environmental improvement and competitiveness come together." [13] This brings Porter back to his basic hypothesis that holds superior productivity as the most important source of competitiveness. The focus for the advantage of induced competition is in Porter's view located at the level of individual industries, and must comprise a self-supporting continuous process of improvement with its own momentum based on the enhanced efficiency of resource usage. As far as individual companies are concerned, the competitive advantage is directly generated internally, i.e. within the manufacturing process. However, advantages arising from the efficient use of resources do not only take the form of reduced emissions and by-products or the optimised use of resources in the manufacturing process. Innovations may also result in improved product qualities or characteristics. Furthermore, the safety and resale or scrab value of products may be raised while unit and disposal costs are decreased [15].

Success factors for innovation and their implication for strategy types

The underlying success factors for innovation. Innovation effect overcompensates the costs of regulation and innovation. The factor which is decisive for the success of compensating by innovations is the way in which a set of parameters relevant to innovations is affected by environmental regulation. These parameters critical to success occur in advance of the innovation itself and have an impact on the potential implementation and success of innovations.

Regulation causes *costs* (charges, taxes and other financial contributions) – and hence, as far as companies are concerned, involves an additional strain on their limited financial resources. This frequently necessitates redistributing the internal financial budget, which in turn jeopardises the success of innovations in two ways. First of all, regulative demands may tie up innovation capital 'unproductively', hence limiting the scope for new products or processes; moreover, budgets for research and development may also be redistributed [2]. Furthermore, the process of adaptation and meeting regulative demands is time-consuming and creates '*time* costs' [4, 16]. When new products are launched, the delays involved may be crucial for the success or failure of an innovation project. Particularly in the environmental protection sector, being an innovation leader or follower is highly important. Given the shortened amortisation periods of products arising from reduced market life cycles next to longer development periods, technological leadership appears to be an advantageous strategy. High levels of synergy with the existing product programme and the manufacturing process are beneficial for technological leadership, while high product complexity and rapid market development pose high entry barriers for competitors. However, the advantages of technological leadership are accompanied by risks such as dependence on a certain technology path, high market entry costs and the possible competition from the company's own products ('cannibalisation effect'). Delayed market entry owing to environmental regulations reduces the likelihood of the innovation leader succeeding. At the same time, the pressure on the amortisation period is increased by the regulation costs. *Uncertainties* are another parameter critical for innovations which can be influenced by regulation [4, 13, 17]. Abernathy/Utterback [18] distinguish between two types of uncertainties characteristic of a process of innovation: (i) uncertainty concerning opportunities of technological development and (ii) uncertainty regarding opportunities of application and the chances of competitive success. How regulation influences types of uncertainty varies. Development and innovation decisions in new technologies are protected [14, 16]. Anticipating a social trend (such as a high degree of environmental awareness) may, however, increase market uncertainty if markets for these products and services are not yet existing. The increased uncertainty about the success of innovations arising from regulation is reflected in a higher risk premium when assessing investment decisions, reducing the number of promising innovation projects [2].

Hence costs, time and uncertainty are critical success factors for innovation caused by regulation. It must be stressed again that the implications for the competitiveness and innovative ability of individual industries can only be determined in the context of the strategy types, cost leadership and differentiation.

Implications of critical success factors for strategy types

The effects of costs, time and uncertainties for cost leadership and differentiation. The effects of an environmental regulation on competition and innovation vary depending on the strategic management concept adopted (cf. Fig. 3). In the case of cost leadership, company size and the economies of scale in the mass market have a favourable impact on decreasing the costs for compliance. Since the pressure to redistribute R&D funds is not mandatory, the cost burden will not negatively affect production innovations. However, incentives are highly likely to emerge for the reorganisation of the production process. In the long term, integrated production technologies [19] are advantageous over end-of-pipe solutions. With their inherent environmental protection, improved resource productivity and more efficient resource use are incorporated and they do not tie up capital unproductively. With cost leadership, the time factor does not directly lead to discernible effects on innovation, although to a certain extent the uncertainty across the width of future technological developments will be reduced. As far as process technologies are concerned, the role of the technological leader is strengthened, hence rewarding innovative pioneering achievements.

In the differentiation strategy, the critical factors for innovation success are weighted differently, resulting in different stimulations for innovation. Costs directly attributable to regulation unfold due to the smaller company size, the smaller assigned market segments and the lower capital stock in a much bigger impact on innovation than in cost leadership. In order to achieve rapid compliance under the terms of a thin capitalisation, the costs caused by regulation need to be covered by reallocating funds from the R&D budget. Short-term compliance activities make it difficult to perceive competitive advantages and innovation potential. Moreover, the time needed to develop and implement compliance strategies jeopardises innovation. Differentiation advantages are based on the efforts of being able to respond quickly and flexibly to customers demands. Given the prospect of regulation delaying the market launch of innovations, companies risk losing their competitive advantage permanently and the incentive structures for innovations may be neutralised. This negative effect manifests itself in decreased innovation rates. However, whether the quality of innovations will change can only be assessed by taking into account other internal and sector-specific factors. Regarding the success of product technologies, additional uncertainty builds as soon as environmental regulation anticipates changing consumer needs, calling into question whether a market for the products or the products itself still exists. The challenge consists in developing lead markets [20, 21] in which companies with the differentiation strategy can find opportunities for innovations and early-mover advantages.

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The Diamond Framework developed by Porter highlights how focusing on strategic management concepts affects the competition and innovation strategy.

The fact that environmental regulation has a major influence on competitiveness and innovation (the Porter Hypothesis) became apparent from the regulation-related innovation parameters critical to success costs, time and uncertainty.

By considering both strategy types broken down into cost, time and uncertainty factors, different innovation effects were ascertained. The following section transfers the findings obtained to new chemicals regulation's effects on competition and innovation.

II. Characterisation of the chemicals sector and the new European chemicals legislation

Characterisation of the chemicals sector

The some 25,000 companies in the chemicals industry in the EU have an annual turnover of €534 billion [22]. The chemicals industry comprises 2.4 % of the EU gross domestic product, employs a total staff of about 1.7 million, or 7% of the overall workforce in the manufacturing industry, and accounts for approximately 12% of the EU manufacturing industry's gross value. These clearly added a major economic factor (cf. Fig. 4). However, the function of SMEs in the chemicals industry deviates from that prevailing in other types of manufacturing industry.

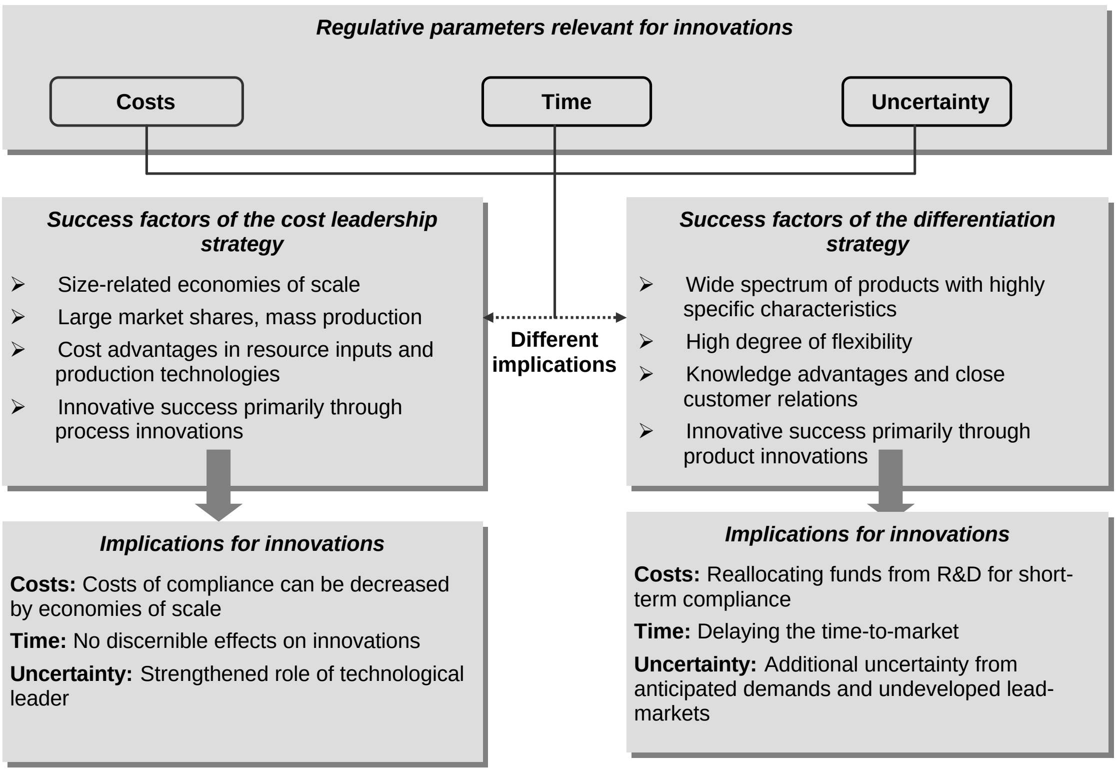

Figure 3: Different implications of regulative parameters on success factors in the strategy types

Whereas in many other sectors, small and medium-sized enterprises mainly act as suppliers, in the chemicals industry the production of basic substances is mostly the realm of large companies.

In contrast, SMEs tend to produce final chemical products (formulations and preparations) and are – like large blue chip companies – represented on world markets [23]. Small and medium-sized enterprises offer a large number of products to counter the high structural concentration linked to high turnover and a huge workforce. The chemicals industry is a cross-sectional industry by nature and is characterised by large structural diversity. The manufacture of a broad range of products – both basic substances for the chemicals industry itself and other industrial sectors as well as special preparations for final consumption – is characteristic of this diversity. Owing to the high degree of vertical integration, more than a third of demand for chemical products comes from the chemicals industry itself. One special feature of the chemicals industry is by-production of substances. Close product links in the manufacturing process of usable main products and by-products lead to closely interdependent relationships and sensitivity to changes within a production chain.

Above all, the chemicals industry differs from other sectors regarding the heterogeneity of its products. This diversity can be attributed to the special circumstances of the production process. A classification into certain product groups has proved useful. Kline [24] distinguishes between basic chemicals, industrial products, fine chemicals and specialty chemicals (cf. Fig. 5).

The classification of chemicals within a product group matrix depends on production quantities and the degree of differentiation. The advantage of this arrangement is the possibility to derive innovation strategies.

Different technological development tendencies result from the product group matrix. New products introduced are mainly in the group of fine chemicals and specialty products – which are usually sold at high prices and produced in low quantities. These product segments feature high profit margins and low competitive pressure, and are closely costumer-oriented. Fine chemicals are distinguished from the special performance characteristics of specialty products by virtue of their high quality and purity [25]. The prevailing technological priorities in these areas are product development and improvement. As far as the mass-production of basic chemicals and industrial products are concerned, the situation is reversed. Basic chemicals form the basis for production in the chemicals industry. Industrial chemicals provide fundamental manufacturing technologies for economic sectors outside the chemicals industry. These two product groups are typically in the phase of technological maturity. Innovations are largely restricted to process innovations; production developments and innovative applications are less frequent (but cannot be ruled out altogether) [3].

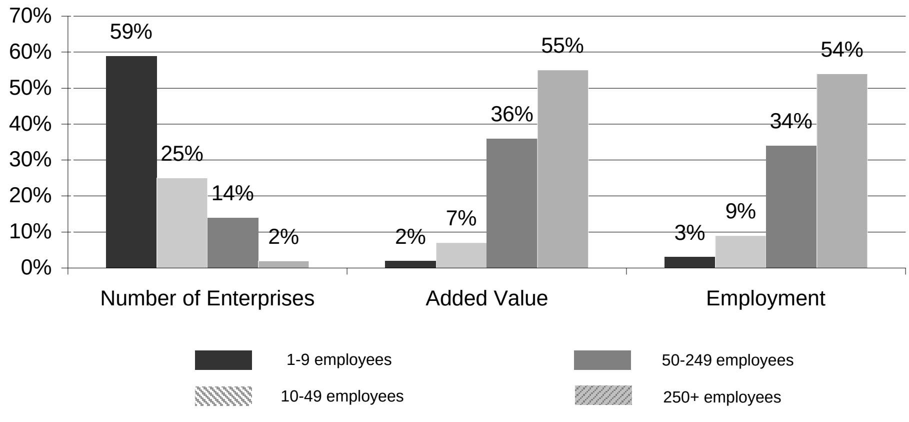

Figure 4: Facts and figures for the chemicals industry [22]

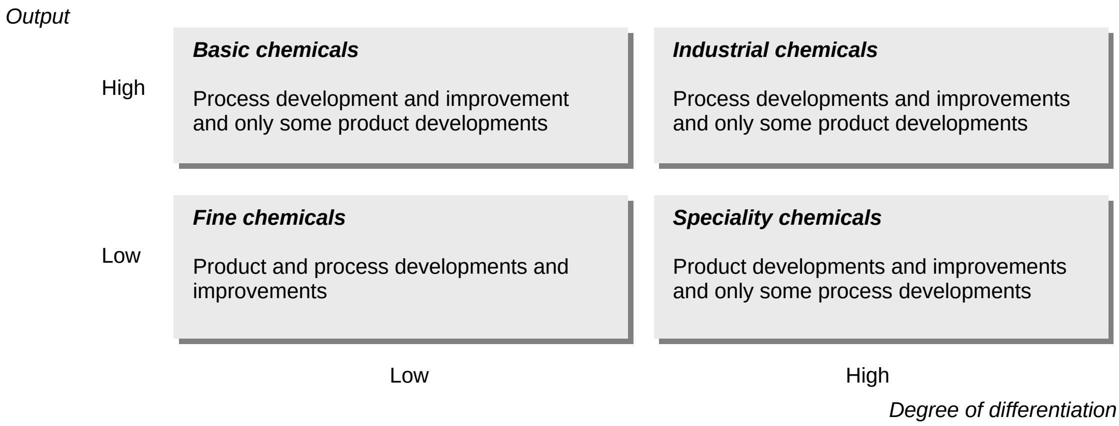

Figure 5: Product group matrix in the chemicals

The product group matrix also provides information about the concentration of firms in specific market segments. The high capital intensity in the manufacture and formulation process of basic chemicals necessitates a certain company size. At the other end of the scale, the production of fine and specialty chemicals is characterised by a high grade of flexibility and knowledge intensity, and this upper are market segments mostly engaged by SMEs. Product innovations by SMEs are usually preparations and formulations – in other words, innovative applications of existing substances [26].

Referring back to the strategy types mentioned by Porter, the chemicals industry can be summed up as follows: basic industry provides large quantities of chemical products and hence requires a certain company size. Due to technological maturity, competitive advantages are mainly achieved in the form of lower costs (cost leadership) and process innovations. SME's dominate the downstream industry of specialty and fine chemicals with a huge variety of different products; flexibility and rapid market entry are important parameters of success. Apart from the restructuring processes to be observed among traditional chemical manufacturers all over the world [27], the increased importance of product innovations indicates the limited scope for innovation in basic chemicals. This is a market segment which is being increasingly characterised by the entry of competitors from third countries with their own resources and who can take on the downstream processing steps at the end of the supply chain [28].

The structure of the new European chemicals regulation: the REACH system

The new European chemicals regulation is designed to ensure the safe production, usage and application of chemicals. Under the principle known as 'Duty of Care,' which protects human health and the environment, manufacturers, importers, formulators and users are obliged to reduce the risks of handling chemical substances and preparations. This new risk management is expressed by the fact that the burden of proof is now on industry (primarily manufacturers and importers) to provide information about the properties of chemicals, their intended uses and their exposition respectively. However, formulators and users are also involved in this product responsibility whenever 'unintended uses' occur. The present division of chemicals into new and existing substances is to be abolished and a joint chemicals control system set up. At the core of the new European chemicals regulation is the REACH system (Registration, Evaluation, Authorisation of Chemicals):

- *Registration* of the approximately 30,000 chemical substances produced in quantities of at least 1 ton annually. The registration procedure is designed according to a threshold approach (cf. Tab. 1). Registration and provision of information about the properties and uses of chemical substances are now the responsibility of manufacturers throughout the supply chain, be they substance producers or formulators of preparations. SMEs in the chemicals industry tend to operate in the low-tonnage range, underlining the importance of

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this class of enterprises as specialised manufacturers whose competitive potential lies in using a large number of substances used in small amounts.
The information gathered upon registration provides a basis for efficient risk management. The burden of proof and the costs of registration are borne by the chemicals industry.

- *Risk evaluation* of chemicals exceeding production volumes of at least 100 tons per annum (about 5,000 substances) and those of lower volumes where there exists a concern. The relevant authorities are responsible for evaluation, which includes the development of substance-tailored testing programmes.

- *Authorisation* of chemical substances with properties that give a very high cause for concern. Substances that are carcinogenic, mutagenic or toxic to reproduction as well as very persistent and very bio-accumulative pollutants require authorisation before they may be used for a certain purpose, irrespective of the tonnage threshold. The European Commission expects this category to cover about 1,400 substances. The burden of proof and the registration costs are to be borne by the chemicals industry.

Cost and time implications of the REACH system

The economic effects for competitiveness and innovations of the new chemicals regulation arise from the structure of the REACH system. Being a cross-section industry, the chemicals industry has the function of an innovation supplier [30]. An extensive preliminary input involving intensive research by the chemicals industry is the basis of not just the chemicals industry's own competitive potential, but also the technology management of different downstream industries in the manufacturing and process-related use of chemical substances.
The REACH system comprises regulative parameters which affect competitiveness and innovation both directly and indirectly. Inherent economic effects lie in two aspects of the REACH system, the cost burden and the time factor applied. The economic implications are chiefly connected to the registration and authorisation procedure. The regulation has a direct impact since the opportunities to innovate, as well as the costs and time of innovation are affected directly [26].

The cost burden depends, on the one hand, on the probability of exposure, which in turn requires toxicological and ecotoxicological data ranked in terms of the tonnage threshold. On the other

Production volume threshold			**Percentage of substances produced by large companies and SMEs**			
			Existing substances		Intermediates	
Chemicals to market	Testing requirements for registration	Number of substances	Large	SME	Large	SME
< 1 t/y	No testing required	?	6%	18%	14%	14%
1–10 t/y	Data on physicochemical, toxicological and ecotoxicological properties; testing limited to in vitro methods	19,700	19%	21%	17%	25%
10–100 t/y	Base set testing according to Annex VIIa of Directive 67/548/EEC	4,700	26%	20%	23%	23%
100–1,000 t/y	Base set testing and Level 1 testing	3,000	18%	15%	10%	12%
> 1,000 t/y	Base set testing and Level 2 testing	2,600	32%	23%	36%	26%

Table 1: Key elements of the REACH system [29]

hand, additional tests need to be carried out if specific substance properties are known. In addition to the cost burden, the obligation to produce and submit test data is time-consuming and generates time costs. The costs of the time factor will have an impact on competitiveness of enterprises throughout the supply chain if it counteracts specific competitive advantages or delays the market launch of innovations. However, the time investment will only be relevant to competitive matters once the initial 10-year legal continuation permit expires (time period for completion of registration and testing for chemicals already on the market). After this time period and for new chemicals immediately, the REACH system will take on the character of a approval procedure. Table 2 contains an overview of the estimated costs and time scales of the REACH system.

The indirect impact of the new chemicals regulation on competitiveness and innovation stems from the direct cost and time implications. The companies indirectly affected by the chemicals regulation are not primarily manufacturers of chemical substances but rather companies in industrial sectors who use chemicals in their processes and end-products not previously involved in registration or authorisation. Industrial downstream users working in preparation and formulation are mainly SMEs. If chemical manufacturers and importers are not willing to register and authorise certain substances or uses, the chemical companies downstream face a withdrawl of the source materials they need to process in order to manufacture products for end-use.

The probability of chemicals being rationed will increase given the cost burden per quantity unit to be borne by individual substances under the REACH system. After all, especially subsceptible for non-registration are substances which earn only a small marginal income. As Tab. 3 shows, SMEs' product ranges usually comprise a much smaller number of low-margin substances than is the case with large companies. This underlines the high significance of low-volume, high-margin substances for SMEs, which rely on pronounced flexibility and rapid market entry. This trend is also apparent in the manufacture of intermediate products, where low tonnages are especially economically successful.

By contrast, a far greater number of large companies regard low-volume substances as 'low-valued'. This proportion declines with larger production quantities (over 100 tons per annum). The high testing and registration costs in relation to low quantities make the rationing of certain product groups with low-margins likely. Nevertheless, estimates indicate that not all 'low-value' chemicals will be rationed. Even if the additional costs cannot be recovered in the short or medium term, there are various reasons why manufacturers, importers and processors may still carry out registration [29]. Numerous by- products of high-value chemical products arise in the

	Costs			Time*		
Registration	EC	RPA	VCI	Testing	Research, validation	Exposure criteria, provisional risk assessment, documentation
1–10 t/y	€ 20,000	€ 31,400	€ 50,000	3 months	2 months	1 month
10–100 t/y	€ 85,000	€ 155,000	€ 140,000	9-12 months	2 months	2 months
100–1,000 t/y	€ 250,000	€ 420,000	€ 370,000-410,000	12-24 months	3 months	4 months
>1,000 t/y	€ 325,000	€ 683,000	€ 650,000-740,000	12-60 months	6 months	9 months
Evaluation	No costs for enterprises			-		
Authorisation	€50,000			-		

Table 2: Cost and time implications of the REACH system [29, 31, 32]

Quantity (t/y)	Percentage of chemicals by tonnage considered to be of low value				Percentage of total products likely to be withdrawn from production			
	Large		SME		Large		SME	
	Chemicals to market	Inter-mediates	Chemicals to market	Inter-mediates	Chemicals to market	Inter-mediates	Chemicals to market	Inter-mediates
1–10	24	16	12	1	12	8	6	0.5
10–100	11	14	13	14	8	10	9	10
100–1,000	5	16	20	19	3	11	16	15
> 1,000	8	14	7	37	4	7	4	23

Table 3: Chemicals of low value and suggested rationalisation effects [29]
* Estimation based on the costs of testing for Intermediates

complex manufacturing processes of the chemicals industry. The registration of these by-products is encouraged by high production quantities and growing demand for the main product. Similarly, a substance may be of relevance for particular customers which also purchase other, more expensive chemicals. In the case of low margins per production unit, meeting the registration costs may also be justified by high production quantities. If no substitutes are available or if a substance decisively contributes to maintaining competitiveness or flexibility, registration on the part of the downstream industrial user may be expected.

To sum up, four factors can be identified which affect decisions about product rationing [29]:

- The estimated registration costs for a substance: the costs depend on the volume threshold, data already available and the cost-sharing among a registration consortium
- Market analyses about current and future market shares and profit margins
- The importance of the chemical or substance in current and future markets, manufacturing processes and applications
- The importance of the chemical or substance for the product portfolio of individual companies and the degree of competition in this product field.

As already outlined in this chapter, the REACH system in the new European chemicals regulation is closely linked to certain critical factors of competitive success. Both the impact of the direct cost and time implications on competitiveness and innovation and the indirect effect of uncertainty on the innovation process differ depending on the strategic orientation in the individual sectors of the chemicals industry [33]. Using the analytical framework presented in section I, the Porter Hypothesis for the chemicals regulation will now be subjected to final review and evaluation. Using this analytical framework will also show the fundamental condition on which the validity of the Porter Hypothesis rests.

III. The Porter Hypothesis in the new chemicals regulation – does it hold?

The impact of the new chemicals legislation on innovation within the cost leadership strategy

Cost leadership has been identified as a strategy which chiefly enables large companies to achieve competitive advantages through economies of scale. The success factors of a comparatively low cost structure combined with low costs for raw materials, energy and manufacturing are unaffected by the new chemicals legislation. The product portfolio of companies in this segment is relatively small, but involves high tonnages of both the chemicals used and the products manufactured.

High volumes involved in economies of scale minimize the financial burden per substance on registration and authorisation costs [34]. Moreover, the time factor resulting from the testing and registration procedure will not impair the success factors typical for the strategic management concept in this production segment. Compliance to the chemicals regulation and compensation for the cost burden resulting from the new regulations are hence negligible with this strategy type and do not have any disadvantages for product innovations. The competitive advantages for these companies arise from process innovations. However, incentives to process innovations and enhanced resource productivity are unaffected by the new regulation.

The existing production structure and value creation, which consists of relatively few basic chemical products but is nonetheless very capital-intensive, means that achieving a first-mover position and innovative advantages are still very important. Yet, the two effects described by Porter are of a technological and a process-orientated nature. An efficient manufacturing process is the basis for securing cost leadership. However, the new chemicals regulation has no discernible impact on success factors which are fundamental to achieving a competitive advantage from cost leadership.

The impact of the new chemicals legislation on innovation within the differentiation strategy

In contrast to the cost leadership strategy, the new chemicals regulation will have a much bigger impact on competitition and innovation in connection with the differentiation strategy. Regulative factors critical for success of the strategy type impede the implementation of the differentiation advantage and restrict innovation.

Competitive advantages from differentiation are mainly achieved by companies in the fine and specialty chemicals sector. One characteristic feature of the manufacturing process in this very large number of individual production segments is the multitude of chemical base materials and intermediate products used in relatively low amounts (typically less than 100 tons per annum). A large available portfolio of base materials forms the basis needed to be able to react rapidly and flexibly to the demands of customers. Changes to specialty and fine products (innovative applications) and new product developments normally result from close customer interaction and specific demands of buyers or changed requirements. Hence the crucial factors for a competitive advantage based on the differentiation strategy are a large pool of chemical substances and preparations that are immediately available, short market entry times, and the protection of knowledge advancements owing to the high capital intensity involved.

The possible loss of the differentiation advantage is based on two effects caused by regulation: (i) restrictions to the flexible response to the need for new products owing to the limitation of the pool of available substances, and (ii) the prolongation of the time-to-market needed for a substance or preparation due to the approval procedure relating to the registration process.

The reduced size of the substance pool available is a result of the costs of registration and authorisation. The limited financial resources of SMEs can generally not afford to register the multitude of substances used and produced and their applications by themselves. Similarly, fine and specialty chemicals are market segments in which registration costs cannot be substantially decreased by means of economies of scale owing to the low production volumes. The partial withdrawal of chemicals and the restriction of market availability will mainly focus on substances which are produced in low quantities and at low profit margins. In particular chemical companies are affected whose competitive advantages are based on rapidly producing very specific low-volume products such as paint or varnish and other chemicals for photography in expensive processes [35]. Because of the cost burden, chemicals in this segment will also experience a negative innovation effect stemming from possible savings in R&D budget and on capital tied up ‘unproductively’. Hence the cost burden accounts for the limited access to the available substance pool. Accordingly, the regulation costs will impair the competitive advantage of flexibility typical of the differentiation strategy. Rationing at the manufacturers level partly also has decisive consequences for the competitiveness and innovation of downstream user sectors if the production process in the supply chain is linked to the immediate availability of high-value innovative chemicals [5, 29].

The demand-based market for fine and specialty chemical products requires rapid customer tailored production. This in turn entails short market cycles and high development expenditures for manufacturers of chemical formulations. However, market entry is delayed by the first-time registration of substances and preparations, the registration of applications and the authorisation of chemical substances (cf. Tab. 2). The implications of the time factor of the REACH system could therefore potentially restrict the differentiation advantage of the rapid and direct market availability of chemical products.

One result of the two effects – the partial ration of the substance pool for chemical source materials and delayed market entry – will be a decline in the rate of innovation. This 'innovation shock' typically occurs in connection with a new regulation [36] and is primarily a result of the cost burden imposed by the new chemicals regulation. Another indirect effect of increasing the costs and time required for innovation is the reassessing "portfolio effect" [26].

The crucial question regarding the competitiveness and innovative potential of the chemicals industry must be about the duration of the negative effects on competition and innovation. The chemical substances already on the market need to be registered within the first ten years following the introduction of the new regulation. The majority of the costs thereby incurred by the industry sector will be appear during this period. However, the duration of the effects caused by the partial rationing of chemical substances is more or less indefinite. The time factor of the new chemicals regulation will only take effect once the initial ten-year period expires. Therefore, the cost burden imposed by the new chemicals regulation will be responsible for the initial size of the innovation shock. However, the cost factor will only be of limited duration, whereas delays resulting from the registration procedure will have a longer-lasting impact, albeit with a less pronounced effect.

One important factor in achieving competitive advantages through differentiation and the implementation of innovations into marketable products is adequate protection for intellectual property [36, 37]. An at least temporary monopoly position is reasonable for the capital-intensive innovations of the chemicals industry in view of the additional costs entailed by registration and authorisation [38]. The new chemicals regulation provides for the protection of intellectual property and thus supports the characteristic feature and competitive advantage of differentiation through innovation. Original notifications will be granted property rights of the registration data for a certain period of time. This will allow monopoly profit to build and registration costs to be payed off. Even before this protection period expires, the new chemicals regulation opens up the prospects of broader market availability and substances being used by other suppliers and processors [39] on the basis of a licence fee or the post-sharing of expenses in the case of joint registration for original notifications.

In contrast to cost leadership, in the differentiation strategy, products and product innovations enable competitive advantages. As claimed by Porter, the REACH system of the new chemicals regulation has indeed been designed in a stringent way such that first-moving and innovation effects can be expected to generate compensating or even overcompensating benefits. However, the effects postulated in the Porter Hypothesis could mostly be prevented, since the new regulation directly influences the success factors of the differentiation strategy via the critical factors of 'cost' and 'time'. As a result, innovation capital is tied up in order to maintain production and value creation, the substance pool is limited and market entry delayed.

The new chemicals regulation is not connected to any direct first-mover effects in international competition, since all substances with an annual production volume exceeding 1 ton are subject to the REACH system. The positive innovation effect expected from the new chemicals regulation – safer chemicals and chemical applications due to the systematic provision, evaluation and management of information about substance properties and exposure – does not make for cost or time advantages in registration.

The implementation of positive innovation effects of the chemicals regulation into a competitive first-mover role is tied to corresponding market demand, which does not necessarily always exist [40]. Furthermore, the development of less harmful substances, which is one aim of the new chemicals regulation, conflicts with certain market demands, because specific substance characteristics are actually required or because certain chemicals cannot yet be substituted [5, 41]. In the Porter Hypothesis, competitive advantages for businesses from regulation result from enhanced resource productivity internally compensating for the regulation and innovation costs. However, an internally generated competitive advantage cannot be achieved through the impact and way of regulation in the differentiation strategy since the new chemicals regulation is aligned towards products, not manufacturing processes. Moreover, in contrast with the Porter Hypothesis, no direct internal competitive advantages result for manufacturers or processors from substance innovations and innovative applications.

The new chemicals regulation has a large impact on the success factors in the differentiation strategy. However, neither a first-moving nor an innovation effect which would enable a competitive lead to emerge from the new regulations. Furthermore, one basic condition of the Porter Hypothesis is not met. The special impact of the critical factors of the regulation along with the market structure and company sizes typical of differentiation mean the regulative and innovation costs will not be internally compensated for. Hence the benefits for competitiveness and innovation claimed in the Porter Hypothesis are not to be expected in the differentiation strategy.

IV. Summary and concluding remarks

Michael E. Porter's hypothesis that a stringent environmental regulation encourages efficiency and innovation and hence helps improve competitiveness is a key argument in the discussion surrounding the positive impact on competition of the new European chemicals regulation. But does his hypothesis really stand up to closer scrutiny?

Both the Porter Hypothesis and the ways environmental regulations affect businesses' competitiveness and innovation are tied to an extensive concept of strategic corporate management [11]. Competition and the forces of competition in an industry emerge from the »Diamond Framework« as the crucial factors influencing innovation. Competition and innovation effects of regulation are in turn rooted in the way the forces of competition are affected. Seen from this angle, the regulation cannot create the advantage itself. Instead, the effects on competition and innovation of an environmental regulation are restricted to accelerating or increasing the chances of achieving a competitive advantage by means of innovation.

Considering the company itself is important for the competitive effect of a regulation. The company is mapped in terms of its competitive strategy concept and the related competitive advantages. Porter distinguishes between two basic concepts of strategic corporate management: the strategy concept of cost leadership and the differentiation strategy. Both strategies are tied to certain market and competition factors. In addition, cost leadership and differentiation feature specific success factors enabling competitive advantages but which are affected differently by regulation. Competitive advantages of cost leadership are based on a comparatively low cost structure and process innovations – success factors which are not affected by the new chemicals legislation. By contrast, the new regulation entails significant implications for competition for specialist companies downstream in the supply chain of fine and specialty chemicals. The impact on costs and delayed market entry limit differentiation advantages and impede innovation. Neither first-moving effects nor overcompensating innovation effects can be easily achieved with the new system of chemicals regulation; the companies concerned deal in products, which do not allow an improvement in resource productivity or internal compensation for the additional burdens.

Consequently, the Porter Hypothesis's claim that the new chemicals regulation will help to improve competition and innovation only holds to a certain extent. It is restricted to an environmental policy which responds to negative environmental effects by using certain production factors and manufacturing technologies. Regulation is needed in such cases owing to production risks, i.e. mainly the possibility of pollution caused by harmful emissions. By-products which arise during the manufacturing process and which cannot be put to any useful purpose may harm environmental compartments or be hazardous to health. Consequently, such regulations are designed to focus on environmental media affected by problematic substances. Hence, the Porter-Hypothesis works well in terms of encouraging innovations for enhancing resource productivity.

Unlike such environmental protection regulations, the new chemicals regulation is directed at the substances produced and marketed by chemicals companies. Dumping chemicals into the environment in terms of products is the fundamental aim of the chemicals industry [28]. These product risks can be regarded as the main source of generating risks by the chemicals industry. Products as emissions ultimately determine the reason for intervention by means of chemicals regulation. However, the "Risk reduction activities (…) seem less likely to fit the Porter Hypothesis." [42]. Therefore, the Porter Hypothesis does not provide a sound argument that the new chemicals regulation will have a positive impact on competition and innovation. In fact the understanding of corporate strategies, forces of competition and the regulation upon which the Porter Hypothesis is based seems to indicate that certain segments of the chemicals industry will in fact suffer negative effects on competition and innovation.

Acknowledgement

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References

[1] A. B. Jaffe, S. R. Peterson, P. R. Portney (1995), "Environmental Regulation and the Competitiveness of U.S. Manufacturing: What Does the Evidence Tell Us?", *Journal of Economic Literature*, Vol. 23, March 1995, pp. 132–163.

[2] G. Becher, H. Böttcher, R. Funk, V. Hartje, G. Klepper, A. Silberston, R.-U. Sprenger, W. Weibert, (1990), "*Regulierungen und Innovation – Der Einfluss wirtschafts- und umweltpolitischer Rahmenbedingungen auf das Innovationsverhalten von Unternehmen*", Ifo-Studien zur Umweltökonomie 13, München.

[3] N. A. Ashford, G. R. Heaton, (1983), "Regulation and Technological Innovation in the Chemical Industry", *Law and Contemporary Problems,* Vol. 46, No. 3, pp. 109–157.

[4] N. A. Ashford, C. Ayers, R. F. Stone, (1985), "Using Regulation to Change the Market for Innovation", *Harvard Environmental Law* Review, Vol. 9, No. 2, pp. 419–466.

[5] ADL (Arthur D. Little), (2002), "*Wirtschaftliche Auswirkungen der EU-Stoffpolitik*", Bericht zum BDI-Forschungsprojekt, (unpublished).

[6] Mercer Management Consulting, (2003), "*Study of the Impact of the Future Chemicals Policy*", Final Report (unpublished).

[7] IEH Institute for Environment and Health, (2001), "*Testing Requirements for Proposals under the EC White Paper 'Strategy For A Future Chemicals Policy*", An IEH report for the Department of the Environment, Transport and the Regions (unpublished).

[8] Council of Environmental Experts (Rat von Sachverständigen für Umweltfragen), (2003), "*Zur Wirtschaftsverträglichkeit der Reform der Europäischen Chemikalienpolitik*", Stellungnahme Nr. 4, Juli 2003.

[9] M. E. Porter, (1991), *Nationale Wettbewerbsvorteile - Erfolgreich konkurrieren auf dem Weltmarkt*, München, Droemer Knaur.

[10] M. E. Porter, (1990), "The Competitive Advantage of Nations" *Harvard Business Review,* March/April, pp. 73–93.

[11] M. E. Porter, (1999), *Wettbewerbsstrategie*, Frankfurt/M, Campus.

[12] R. Schmidt, (1991), *Umweltgerechte Innovationen in der Chemischen Industrie*, Ludwigsburg und Berlin, Wiss. & Praxis.

[13] M. E. Porter, C. van der Linde, (1995), "Toward a New Conception of the Environment–Competitiveness Relationship", *Journal of Economic Perspectives*, Fall 1995, pp. 97–118.

[14] A. B. Jaffe, R. G. Newell, R. N. Stavins, (2001), "*Technological Change and Environment*", Discussion paper 00-47 REV, Resources for the Future, Washington, D.C.

[15] M. E. Porter, C. van der Linde,n(1995), "Green and Competitive: Ending the Stalemate", *Harvard Business Review*, September/ October, pp. 120–134.

[16] Kurz, R./Graf, H.-W./Zarth, M. (1989), *"Der Einfluss wirtschafts- und gesellschafts-politischer Rahmenbedingungen auf das Innovationsverhalten von Unternehmen"*, Gutachten im Auftrag des Bundesministeriums für Wirtschaft, Tübingen, Institut für Angewandte Wirtschaftsforschung .

[17] A. B. Jaffe, R. G. Newell, R. Stavins, (2002), "Environmental Policy and Technological Change", *Environmental & Resource Economics*, Vol. 22, No. 1–2, June 2002, pp. 41–69.

[18] W. J. Abernathy, J. M. Utterback, (1978), "Patterns of Industrial Innovation", *Technology Review*, June/July, pp. 41–47.

[19] Hemmelskamp, J. (1997): "Umweltpolitik und Innovation – Grundlegende Begriffe und Zusammenhänge", *Zeitschrift für Umweltpolitik & Umweltrecht*, No. 4, pp. 481–511.

[20] M. Beise, K. Rennings, K. (2001), *"Lead Markets of Environmental Innovations: A Framework for Innovation and Environmental Economics"*, Discussion Paper No. 03–01. Centre for European Economic Research, Mannheim.

[21] M. Beise, T. Cleff, O. Heneric, C. Rammer, (2002), *"Lead Markt Deutschland – Zur Position Deutschlands als führender Absatzmarkt für Innovationen"*, Endbericht, Dokumentation Nr. 02–02, Centre for European Economic Research (ZEW), Mannheim.

[22] Cefic, (2004), *"Facts and Figures: the European Chemical Industry in a Worldwide Perspective"*, July 2004, (unpublished).

[23] BIPE Consulting, (1998), *"To Improve the Framework for SMEs in the Chemicals, Plastics, Rubber and Related Sectors"*, Final Study for Commission DG Enterprise.

[24] C. Kline, (1976), "Maximizing Profits in Chemicals", *Chemtech*, Vol. 6, No. 2, pp. 110–117.

[25] Europäische Kommission, (1998), *"Industrial Restructuring in the Chemical Industry"*, Final Report prepared for the European Commission DG III-C-4.

[26] M. Fleischer, (2001), *"Regulierungswett-bewerb und Innovationen in der Chemischen Industrie"*, Discussion Paper FS IV 01-09, Wissenschaftszentrum Berlin.

[27] A. Arora, A. Gambardella, (1998), *"Evolution of Industry Structure in the Chemical Industry"*, In: A. Arora, R. Landau, N. Rosenberg, N. (ed.): Chemicals and Long-Term Economic Growth, New York, John Wiley & Sons, pp. 379–414.

[28] G. Benzler, (1998), *"Chemiepolitik zwischen Marktwirtschaft und ökologischer Struktur-politik"*, Wiesbaden, Deutscher Universitäts-Verlag.

[29] RPA Risk & Policy Analysts (2003), *"Assessment of the Business Impacts of New Regulations in the Chemicals Sector, Phase 2: Availability of Low Value Products and Product Rationalisation"*, Final Report for European Commission DG Enterprise.

[30] C. Rammer, O. Heneric, W. Sofka, H. Legler, (2003), *"Innovationsmotor Chemie – Ausstrahlung von Chemie-Innovationen auf andere Branchen"*, Studie im Auftrag des Verbandes der Chemischen Industrie e.V., Mannheim.

[31] Europäische Kommission (2001), *"Weißbuch – Strategie für eine zukünftige Chemikalien-politik"*, KOM (2001) 88 endg.

[32] VCI (Verband der Chemischen Industrie) (2002), *"Auswirkungen des EU-Weißbuches auf deutsche Chemieunternehmen"*, (unpublished).

[33] K. Esteghamat, (1998), *"Structure and Performance of the Chemicals Industry under Regulation"*, In: A. Arora, R. Landau, N. Rosenberg, (ed.): Chemicals and Long-Term Economic Growth, New York, John Wiley & Sons , pp. 341–378.

[34] K. B. Belton, (2002), *"Is the Proposed EU Chemicals Policy a Good Investment?"*, Discussion Paper, APPAM Fall Conference.

[35] Cefic (2002), *"Business Impact Study – Sectoral Fact Sheets"*, (unpublished).

[36] S. Mahdi, P. Nightingale, F. Berkhout, (2002), "*A Review of the Impact of Regulation on the Chemical Industry*", Final Report to the Royal Commission on Environment Pollution. SPRU, University of Sussex, Brighton, UK.

[37] F. Reinhardt, (1999), "Market Failure and the Environmental Policies of Firms – Economic Rationales for 'Beyond Compliance' Behavior", *Journal of Industrial Ecology*, Vol. 3, no. 1, pp. 9–21.

[38] R. Landau, (1998), "The Process of Innovation in the Chemicals Industry" In: A. Arora, R. Landau, N. Rosenberg, (ed.): Chemicals and Long-Term Economic Growth, New York, John Wiley & Sons, pp. 139–180.

[39] G. Winter, N. Wagenknecht, (2003), "*Multiple Use of Test Evidence under EC Chemicals Legislation and EC Basic Rights: is there Intellectual Property in Administrative Information?*", *RECIEL* 12/2003, pp. 69–83.

[40] K. Bizer, M. Führ, (1999), "Produktrisiken und ihre Bewältigung – am Beispiel organischer Lösemittel in Farben und Lacken", *Zeitschrift für angewandte Umweltforschung*, Sonderheft 10/99, pp. 206–217.

[41] B. Bonifant, (1994), "*Competitive Implications of Environmental Regulation in the Paint and Coatings Industry*", Case Study prepared for the Management Institute for Environment and Business, Washington.

[42] B. Sinclair-Desgagné, (1999), "Remarks on Environmental Regulation, Firm Behavior and Innovation", *Série Scientifique CIRANO*, No. 20/99, Montreal.

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Practicioner's Section

Futuring in the European Chemical Industry

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Abstract: With the beginning of the new millennium there seems to be growing interest in foresight and futures studies. What was once seen as an intuitive skill practised by individuals with more or less success has grown into a coherent body of techniques and knowledge increasingly described as "futuring" and practised by "think tanks" and professional futurists around the world [1]. It is therefore no surprise that these methodologies are also used in the chemical industry in order to cope with the growing uncertainty and volatility this industry has to deal with. More exceptionally, in the last couple of years different independent industry - wide initiatives were started to evaluate the future of the chemical industry. While in the US the focus was on technology there was in Europe a broader perspective. The European Chemical Marketing & Strategy Association analysed the future success factors, the UK initiative developed a vision for a competitive chemical industry in the UK and the European Chemical Industry Council (Cefic) developed different alternative scenarios in order to objectify the dialogue with the EU Authorities. Despite the differences in the approach there is common learning and the understanding that industry-wide futuring is a valid step in order to create a sustainable future.

1 This article is written in a personal capacity and does not necessarily represent the views of BASF and/or of the different organizations mentioned.

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1. Introduction

The growing awareness of futuring in today's chemical industry is not focused on new breakthrough innovations and ground - breaking applications but on concerns about the future of the industry. There is already talk about tomorrow's steel industry with only a few big players left and tomorrow's textile industry with migration from the industrialized countries to Asia and/or the Middle East [2]. In addition, the chemical industry, despite significant investments in environmental standards, is again becoming the target of non-governmental organizations demanding stricter regulations and trying to convince the politicians to increase the regulatory burdens.

This explains the initiative of the European Chemical Industry Council (Cefic) to develop scenarios for the future of the European chemical industry [3] and also explains the idea of the UK Government [4] to think about a vision for the industry. The forerunner of these new chemical futuring initiatives was the 2010 concept of the European Chemical Marketing and Strategy Association (ECMSA) [5]. In contrast to these comprehensive approaches, technical and business leaders in the U.S. chemical industry focused on needs in research and development when they started to develop "Technology Vision 2020" for the future of the U.S. chemical industry in 1994 [6]. Different associations formed the Technology and Manufacturing Competitiveness Task Group with the charter to

- "provide technology vision and establish technical priorities in areas critical to improving the chemical industry's competitiveness
- develop recommendations to strengthen cooperation among industry, government and academe and
- provide directions for continuous improvement and <u>step</u> <u>change</u> technology."

Finally 4 technical disciplines were selected as crucial to the progress of the chemical industry:

- "new chemical science and engineering technology
- supply chain management
- information systems and
- manufacturing and operations."

In addition to these technology issues, the concept of sustainable development was analysed and ideas for partnerships among industry, government and academia were reviewed.

The recommendations led to the development of Technology Roadmaps [2][7] in fields like

- bio-catalysis
- combinatorial chemistry
- nano-materials
- reaction engineering
- separations
- etc.

The aim of these roadmaps is to provide a chronological path to achieve the vision.

In order to be successful it was recommended that collaborative R & D be done. Today, "Vision 2020" is an

- Industry - led partnership - public and private
- on-going collaborative process to faster technology innovation.

Despite the narrow focus of this early initiative from the US chemical industry, it has the same objective as the subsequent initiatives: to improve the competitiveness of the Chemical industry in a rapidly changing business environment.

The US initiative identified 5 major forces as crucial challenges:

- increasing globalization of markets
- societal demands for higher environmental performance
- financial market demands for increased profitability and capital productivity
- higher customer expectations and
- changing work force requirements.

[2] For access to the different road maps see [7]

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And, in addition to the technical recommendations, the following steps were demanded:

- generate and use new knowledge
- capitalize on information technology
- encourage the elimination of barriers
- work to improve the legislative and regulatory climate
- improve logistics efficiencies
- increase agility in manufacturing
- harmonize standards
- create momentum for partnering
- encourage educational improvements

Today, it is obvious that not all company leaders in the chemical industry followed this advice. And in a recent article David Proctor states that the North American chemical industry is under serious threat [8].

In the following chapters we will focus on futuring initiatives in the European chemical industry and compare them at the end with the U.S. initiative.

2. ECMSA Scenarios 2010

The European Chemical Marketing and Strategy Association (www.ecmsa.org)) started its scenario 2010 project in 2000 together with its partner organizations CDMA (the Commercial Development and Marketing Association) and LES International (Licensing Executives Society International). The starting point of this initiative was the realization that the chemical industry is facing major structural changes (see figure 1) which make it impossible to predict the future. Therefore it was decided to use the scenario approach as the basic methodology for evaluating the major external driving forces and the processes of adaptation by the industry.

The scenario approach consisted of two steps. Phase 1 was a top down perspective looking at the industry as a whole. Phase 2 was a bottom up approach looking in detail at the petrochemicals/plastics and fine chemicals/specialties sectors of the industry.

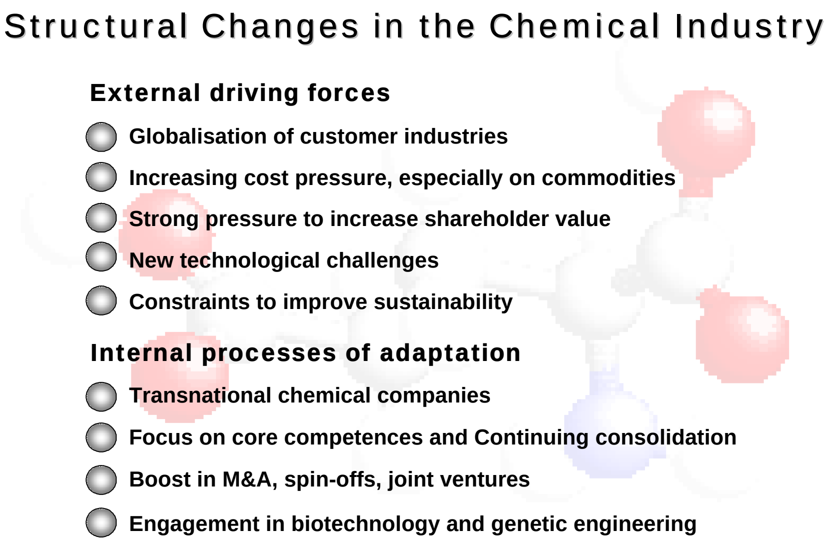

Figure 1: Structural Changes in the chemical industry

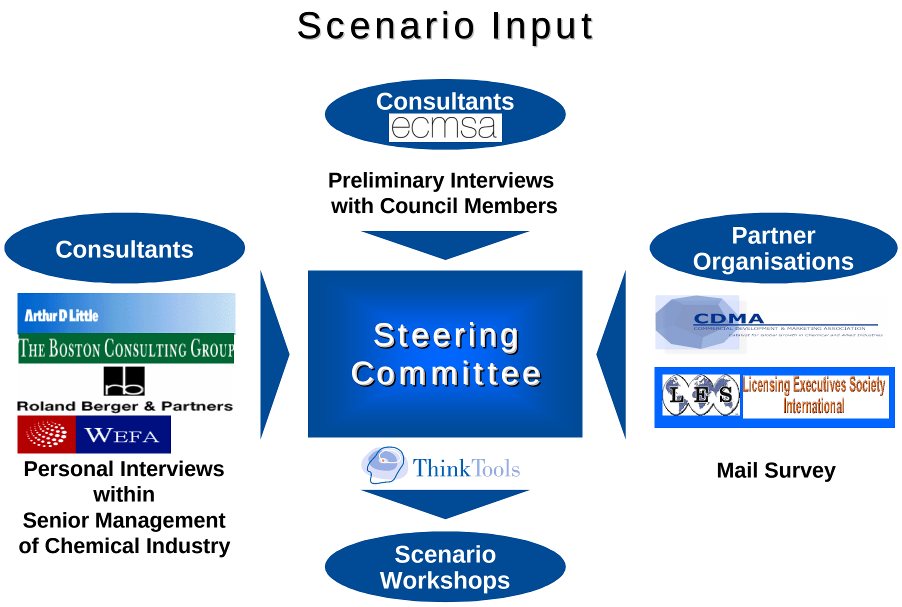

Figure 2: Scenario Input

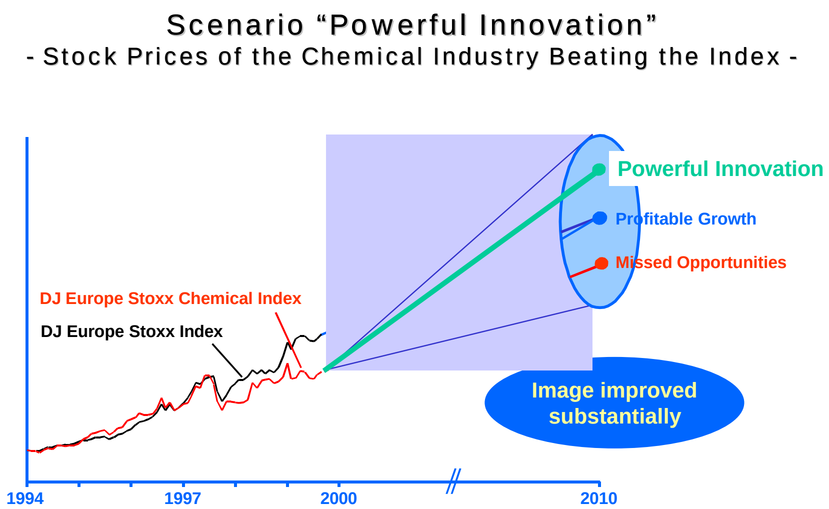

Figure 3: ECMSA Scenario "Powerful Innovation"

2.1 Top-down scenarios

The scenarios for the overall chemical industry depended on the inputs (see figure 2) from the European chemical industry (ECMSA Members), ECMSA partner organizations and consultants

This input was the starting point of intense scenario workshops based on the methodology from Think Tools®. This software together with the strong support from facilitator Adrian Taylor from Think Tools® helped to integrate different points of view, controversial opinions and often difficult discussions. Finally, we were able to agree on 3 different possible and realistic futures for the chemical industry:

- Powerful innovation - as the most promising optimistic perspective based on technological breakthroughs especially in biotechnology
- Profitable growth - as a still positive future development, but relying more on globalisation than on new technologies
- Missed opportunities - as a very negative scenario with negative macroeconomic developments as well as a lack of proactive action from the industry

The "powerful innovation" scenario (see figure 3) shows a future where the European chemical industry is able to beat the European Stoxx Index and improves its image among the public significantly.

But this scenario has a lot of important prerequisites which are difficult to fulfil:

- Comprehensive innovation in all relevant fields
    - product innovation
    - application innovation
    - production process innovation
    - business process innovation
- Strong orientation to customer needs
- Measures to improve attractiveness for highly qualified employees

The "missed opportunities" scenario is characterized by weak macroeconomics, chemical demand below GDP growth and increasing regulation as well as by a low-performing chemical industry (clear lack of profitability, weak stock market performance, intense competition, brain drain). In order to avoid such a negative development, three key success factors were

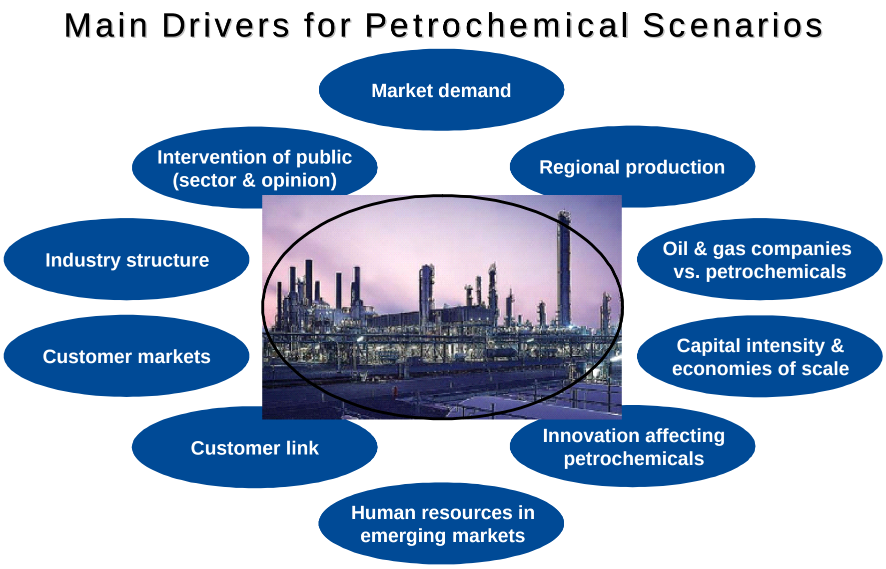

Figure 4: Main drivers for petrochemicals/plastics

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identified:

- Innovation (especially in the fields of biotechnology/genetic engineering, process technologies/catalysis, IT-applications/computing, environmental technologies/ processes, alternative energies/fuel cells, nanotechnology, combinatorial chemistry)
- Customers (especially customer relationship management, knowledge of customer needs and management of a global customer base)
- Employees (especially broadening the skills base in the fields of information technology, marketing and combining natural sciences and economics)

The profitable growth scenario was used as the starting point for the bottom-up scenarios which are described next.

2.2 Bottom-up scenarios

The feedback on the publication of the top-down scenarios was very positive but they seemed to be too generic to represent the complexity of the chemical industry and to illustrate the specific challenges the different industry sectors are facing. Therefore, ECMSA decided to develop specific industry sector scenarios based on the general scenarios.

2.2.1 Petrochemicals/Plastics Scenarios

The starting point of the development of the petrochemicals/plastics scenarios was a list of 10 main critical drivers (see figure 4) which were then analysed with the Think Tools® methodology In the end, four different scenarios were identified:

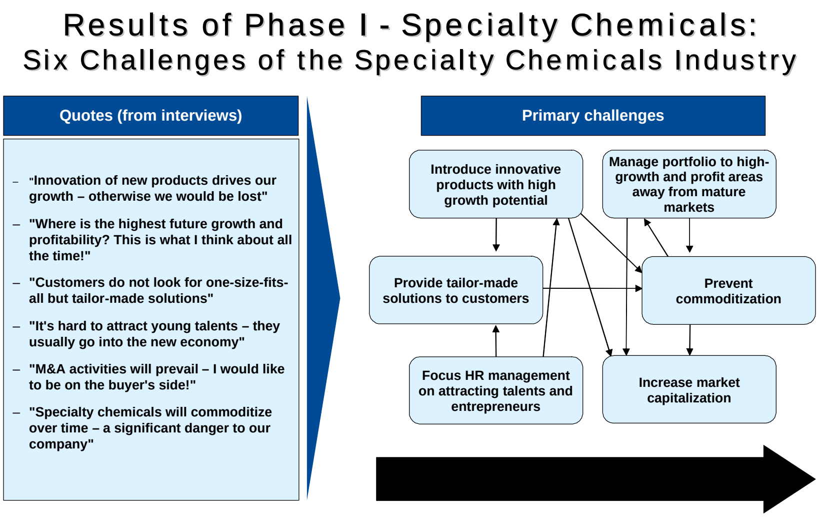

Figure 5: Six challenges of the specialty chemical industry
(source: interviews conducted by Roland Berger & Partners)

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- Industrial countries sustained:
  A petrochemicals/plastics industry which is still prospering in Europe
- Same model new geographies:
  The European petrochemicals/plastics industry migrating to Asia
- Shift to the Middle East:
  The Middle East is dominating the global petrochemicals/plastics industry
- Tables turned:
  Producers from the Middle East and Asia invest in Europe

The discussion with the different players in the European petrochemicals/plastics industry after the publication of these scenarios showed that they helped to stimulate strategic thinking. It should also be mentioned that about one year after publication of the scenarios the Middle East player SABIC acquired the petrochemicals assets from the Dutch company DSM. But up until now, we have not seen a major investment or acquisition from an Asian petrochemicals/ plastics player in Europe with the exception of Reliance from India acquiring in 2004 the former HOECHST polyester fibre business TREVIRA.

2.2.2 Speciality Chemicals Scenarios

The development of the speciality chemicals scenarios started with the input from Phase 1 (see figure 5) where six challenges were identified. Finally, the following scenarios were found with the Think Tools® approach:

- The Asian Wave: Strong imports from Asia into the European market
- Differentiation by Innovation: Increasing competitiveness by the European specialty chemicals industry with innovative products and applications
- Global Rules: Commoditizing helps European companies which focus on economies of scale and scope
- Breaking the Mould: Reinventing significant parts of the European chemical industry with biotechnology

Looking backwards, it is easy to notice that imports from Asia have grown, but the other scenarios could still happen.

It seems that the ECMSA-Scenario helped to stimulate futuring and scenario thinking in the European chemical industry. But, primarily, increasing competition from Asia and the Middle East and especially pressure from the regulatory side pushed the industry to think more systematically about the future.

3. A vision for the UK chemicals industry

In January 2002 the UK's Department of Trade and Industry (DTI) launched an initiative for a "road map for formulating the actions that need to be taken now to ensure a vibrant and competitive chemical industry in the UK for the future under the leadership of Lord Sainsbury (Parliamentary Under-Secretary of State for Science and Technology)." [9] The "Chemicals Innovation and Growth Team" was established, which during the course of its work,

- "evaluated the key factors impacting on the chemicals industry globally,
- identified the opportunities and challenges for the UK
- formulated a vision of what the future chemicals industry should look like and
- made recommendations for industry, government and others for specific actions."

The vision for the UK chemicals industry was described as "seizing the agenda to profitable growth" [10]

- The chemical industry is seen as part of the solution and not of the problem with a charismatic leadership which addresses its future productivity in two ways:
  - "by being innovative in using science and technology to develop new products and processes
  - and by ensuring its workforce has the right set of skills and competences."
- In addition, the chemical industry has successfully responded to the challenges of sustainable development

- and therefore earned a better reputation.

In accordance with this vision, the Chemicals Innovations and Growth Team developed ten key recommendations [11]:

1. **Form a Chemistry Leadership Council (CLC)**
Headed by Barry Stickings, chairman of BASF (UK/Ireland) this group is already working on all the challenges facing the chemical industry, including raising its public profile and giving the industry a voice.
2. **Set up a Futures Group to develop Policy Frameworks on Sustainable Development, Reputation and Self-Regulation**
In July 2003, the Futures Group concluded that the reputation of the industry would not be improved without firstly addressing the sustainable development recommendation [12]. This in turn could not be addressed effectively without dialogue and stakeholder engagement. Therefore the Futures Group asked “Forum for the Future” to develop a concept for a stakeholder dialogue
Central to the dialogue is the “Sustainability Matrix” which plots the five capitals “Natural, Human, Social, Manufactured and Financial” against “the three ways in which an organization can be considered to manifest’ itself – as a business, as a provider of products and services and finally as a significant member of the wider community.”
3. **Set up a Chemicals Innovation Centre (CIC)** to act as the specialist central hub for the networks relating to innovation and technology and product development. This recommendation is clearly related to the next three recommendations on innovation.
4. The Chemical industry should **develop an agreed view of science and innovation priorities** to communicate with the UK science base.
5. The Chemical Innovation Centre (CIC), with the relevant regional and national agencies should **promote the UK as the location of choice** for start-ups in chemicals and related technologies.
6. The Chemicals Leadership Council should carry out a **review of marketing excellence** in the industry. In order to fulfil all these innovation-related targets, the Chemistry Leadership Council has set up an Innovation Group which is supported by an Innovation Task Force (ITF). They first defined a framework for action [13] and began work on four topics:
    - defining a set of research priorities (In July 2004 the CLC Innovation Task Force published a report on “Research and Technology Priorities”)
    - looking at the entire innovation process
    - evaluating the UK science base
    - supporting the establishment of the Chemical Innovation Centre

    The next three recommendations focus on skills and competencies:
7. **Set up a Skills Network Group** (SNG) to enable the industry to formulate more clearly and inclusively its priorities on skills issues and propagate them through the Sector Skills Councils (SSC) and other bodies, for instance the research councils.
8. The Skills Network Group and the Government should consider how to extend the present remit of the **Process Industry Centre for Manufacturing Excellence**.
9. The **Chemicals Industry should encourage diversity**. The Skills Network Group was formed in mid-2003 and is the largest of the groups representing the chemical industry, the Sector Skills Councils[3], the trade unions, universities and the professional bodies. In July 2004, the Skills Network Group presented to the Chemistry Leadership Council a report on the “Skills for the 21st Century Chemicals Industry”.
The most ambitious recommendation from this report is “setting a Gold Standard for the Chemical industry. This ‘Gold Standard’ should define the skills, competencies and qualifications that the Chemical industry needs if it to be world class”. This Gold Standard should first of all focus on
    - the licence to operate
    - productivity , and later on
    - innovation.

[3] The Organization COGENT has the licence to operate as the Sector Skills Council for the Chemical industry see [14]

10. The UK government, in particular the DTI, should continue to act as a **champion for the industry** and support the work of the Chemistry Leadership Council and its groups (Futures Group, CIC, Skills Network)

Summing up and evaluating the outcomes of the visionary approach of the UK's Chemicals Innovation and Growth Team, we have to admit that it not only produced an interesting and visionary report on the future of the UK chemical industry, but really succeeded in starting many concrete actions.

It seems that the key success factor for this initiative is not only the active participation of the industry and the industry association, but above all the strong commitment of the UK Department of Trade and Industry. The mission statement of this department speaks for itself: "Working with businesses, employees and consumers to drive up UK productivity and competitiveness to deliver prosperity for all." (www.dti.gov.uk)

4. Cefic: European Chemicals Industry Scenarios Horizon 2015

In 2002, the EU authorities requested a view allowing them to understand better the long-term prospects of the European chemical industry and to act accordingly. At that time only players in the European chemical industry (which, by the way, includes thousands of SMEs) and the related manufacturing industries had already realized that Europe's position as a major production and innovation base for the chemical industry was eroding and that additional regulatory burdens could become the last straw. Therefore the European chemical industry Council Cefic (www.cefic.be) started a scenario initiative with the objectives of

- providing Cefic with arguments for the political discussion in the EU,
- supporting the Cefic member organizations with a guideline for dialogue with the national governments,

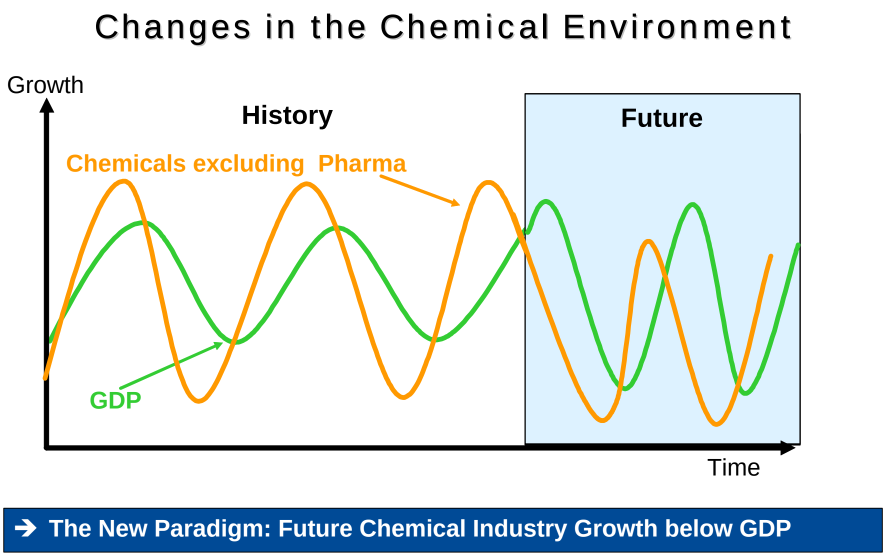

Figure 6: Chemical industry growth versus GDP

- helping the chemical industry in its communication with the financial community,
- underpinning the communication with the public by pointing out the consequences of different developments and
- assisting the chemical industry and Cefic organization in their long-term planning and strategic thinking.

The decision was made to establish a consensus on a set of scenarios based on a comprehensive analysis of the global market environment. The geographic scope was focused on the EU 15 with additional consideration of the 10 new EU member states. The scenario analysis started with macroeconomics and the analysis of the impact of different possible EU developments on the future of manufacturing in Europe and then on the future of the chemical industry in Europe.

4.1 Macroeconomics, customer Industries and the future of the chemical industry

Traditional forecasts assume a strong correlation between chemical demand and the development of the Gross Domestic Product (GDP). This proved to be true for a long time period [15] ,but during the last few years it has become evident that something has changed. In the past, the chemical industry always grew faster than the GDP, but now chemicals growth is below the GDP level and it has to be expected, that this trend will continue (see figure 6). Looking at the components of GDP, it is remarkable that, in the industrialized countries, GDP is more and more driven by the service sector and, because the chemical industry is primarily delivering goods to the production sector (manufacturing, construction, agriculture) the traditional correlation between GDP and chemical demand is fading away.

But this means also that a traditional paradigm has to be skipped: the chemical industry is no longer an engine of growth in the industrialized countries.

As the details of the manufacturing sector were examined further, another structural change appeared: the output of the manufacturing sector in the industrialized countries is growing more slowly than in the past because there is a migration of manufacturing industries from high-cost countries to low-cost countries. This structural shift could be observed in North America when more and more manufacturers delocalized their production from the U.S. to Mexico and nowadays more and more to Asia, especially to China. These migration effects are not totally new and are well known for the textile, shoe and toy industries.

But what is new is that more and more industries are following this trend, and that the speed of migration is increasing.

In Europe, these structural changes happen with a certain time lag in comparison with the U.S. The dominant trend is a shift of manufacturing industries from western Europe to eastern Europe. This shift, which can be observed very well in the automotive industry, especially in the automotive supply industry, is focused primarily on the ten new EU countries. But, for more and more industries, countries like Turkey, Ukraine and Russia are becoming important. And, more and more, the shift of production to Asia, especially China, is becoming attractive.

The good news for the European chemical industry is that as long as its customers stay in Europe – either western or eastern Europe – it does not have a strong impact on production because of the limited distances in Europe. Having these structural changes in mind and understanding the overall trends in the European economics, the macroeconomic scenarios could focus on different political and economic environments (see figure 7).

The four macroeconomic scenarios developed differentiated the future development with regard to the driving forces Globalization, EU Enlargement, EU Governance, Social Responsibility, EU Competitiveness, Sustainability, Demographics/Migration and Innovation/Lisbon Agenda.

The quantification of the four macro economic scenarios was done with the help from Global Insight (www. Globalinsight.com) and their strong global data base on economies and industries as well as their econometric modelling tools.

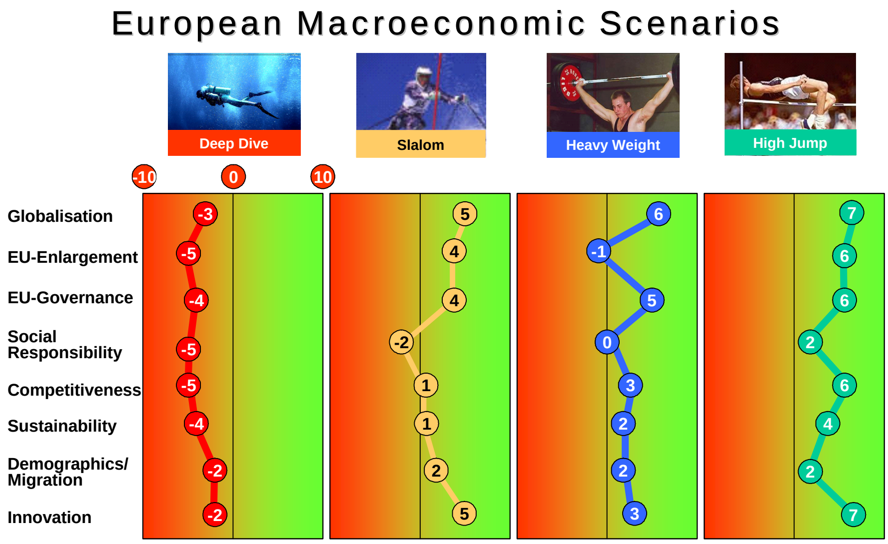

Figure 7: Macroeconomic scenarios (source: CEFIC 2004)

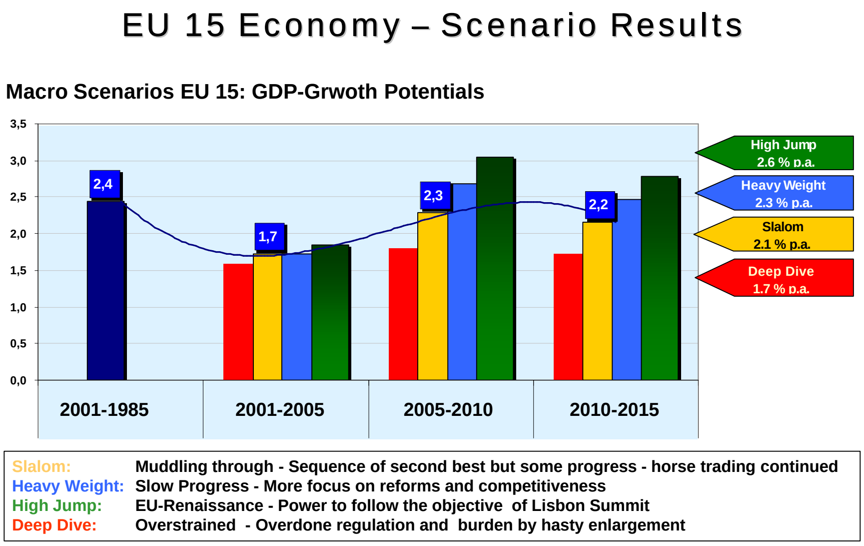

Figure 8: GDP Growth potentials (Source CEFIC 2004)

Despite the enormous efforts invested in the modelling of the four macroeconomic scenarios, they seem not to differentiate a lot with respect to the expected GDP growth rate

(see figure 8). But, because of the huge leverage effect, even small differences count.

4.2 The 4 chemical industry scenarios

The next step after the macroeconomic modelling was the development of the chemical industry scenarios.

This requires not only an understanding of the relationship between the European chemical industry, its customer industries and the European economy within the global context but also an understanding of the critical drivers for the future development, which are specific to the chemical industry. This turned out to be a difficult undertaking because the business environment differs significantly in the different sectors of the chemical industry, because the perception regarding the future challenges differed significantly between the country representatives involved, because the degree of awareness differed significantly between big companies and small/medium-sized enterprises and because the interest in focusing on Europe varied enormously between global players and local companies. To solve these problems it was first decided to look at the chemical industry not only from an overall perspective but also to differentiate between the most important sectors (see figure 9), namely petrochemicals/plastics and fine chemicals/speciality chemicals, and thereby to represent two-thirds of the EU chemicals industry (without pharmaceuticals).

But how to overcome the different perceptions and interests of the people and organizations involved? The solution came with the Think Tools® methodology (www.de.redit.ch), which offers an intelligent combination of a workshop approach together with a user-friendly software package. The powerful facilitator concept and the visualization and consensus-building tools helped to overcome all the problems mentioned above.

This concept helped to identify the critical driving forces for the future development of the European chemical industry as well as to build up different possible and realistic futures for the European chemical industry.

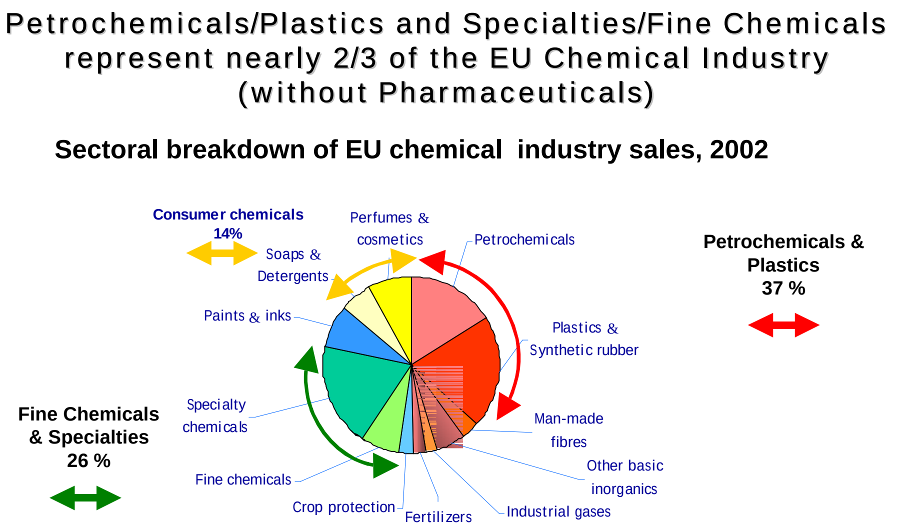

Figure 9: Sectoral breakdown of EU chemical industry

At the centre of all reflections on the future of the chemical industry is the competitiveness of the industry in the global context.

Competitiveness is threatened by a combination of factors, first of all by the regulatory environment, especially the new REACH chemicals policy. But also higher energy prices, higher logistics costs and a business environment that is generally not promoting innovation are playing an important role.

The pressure on chemical prices caused by increasing commoditization, customer trends and growing competition from Asia and the Middle East is seen as an already considerable threat.

On the other hand, the industry itself has the power to increase its competitiveness by restructuring and improving its operational performance, by making use of improved market & sales excellence and more market and customer orientation, and by more, and sustainable, innovation. The results of improved competitiveness would be higher profitability, better payoff, of investments and, together with all the aforementioned actions a better reputation, which would also help to recruit and retain the best work force.

These driving forces are reflected in the four scenarios which were formed as the final outcome of the workshops:

- Sunny: A revitalised EU chemical industry with increased innovation and customer orientation
- Cloudy: A focused EU chemical industry with strengths in high-end products and sustainability
- Rain: A EU chemical industry without confidence in the attractiveness of the European market
- Storm: A shrinking EU chemical industry not able to beat imports

The four scenarios reflect two major dimensions (see figure 10):

- The market situation and
- activities from politics and industry.

The general learning from this scenario approach was that, by joint action by politicians and industry, the competitiveness of the EU chemical industry could be defended or even improved. But without political support the EU chemical industry would lose competitiveness and, in a negative market situation, this could even lead to a shrinking EU chemical industry with a negative impact on the whole European manufacturing industry [16] because of the high importance of chemicals for the production and innovation of finished goods [17]. However, the scenario approach also showed the importance of actions by the industry itself. It has the chance to improve even by increasing competition, but there is a high risk of losing out if it does not take proactive action.

The demands for actions from the political side are

- a balanced chemicals policy
- incentives for innovation
- non-bureaucratic regulations

The action demands for the industry itself are active measures for restructuring[4] innovation in new products, processes and business models increased market & customer orientation and a sustainable balance of economic, ecological and social requirements.

In terms of quantification of the four chemical industry scenarios, the future chemical demand growth differs only by 1.0 % p. a. (see figure 11). But looking at the production side, which reflects competitiveness, the negative scenarios show slow or negative growth in contrast to the positive scenarios with moderate and strong growth.

[4] Even in the field of restructuring support from the EU Authorities seems to be useful. See examples in Chem. System (1998): Industrial Restructuring in the Chemical industry. Final report prepared for the European Commission DG III-C-4 [19]

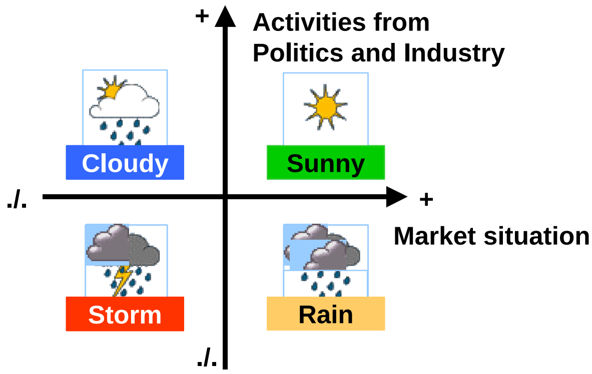

Figure 10: Chemical industry scenarios

Chemical Industry Growth 2002/2015

	Sunny	Cloudy	Rain	Storm
EU Chemical Industry	**+ +**	**- +**	**+ -**	**- -**
GDP *)	**2.5**	**2.2**	**2.1**	**1.7**
Chemicals Demand *)	**2.5**	**2.1**	**1.9**	**1.5**
Petrochemicals / Plastics **)	3.5	3.0	2.1	1.7
Specialties / Fine Chemicals **)	3.7	2.7	2.5	1.7
Chemicals Production	**3.3**	**1.6**	**0.8**	**- 0.6**
Petrochemicals / Plastics **)	3.5	2.0	- 0.5	- 2.0
Specialties / Fine Chemicals **)	5.0	1.0	1.5	- 1.5

*) Global Insight Data, August 2003;
**) Petchems / Specialties = working groups, July/September 2003

Figure 11: Chemical industry growth 2002/2015

What that really means is even better reflected by looking at the chemical trade position which turns negative if industry and politics do not act proactively (see figure 12).

Therefore it was the logical result of this scenario exercise that Cefic recommended the establishing of a Chemical Advisory Networking Group for Europe (CHANGE) consisting of members from

- European Commission
- European Parliament
- Member States
- chemical industry
- trade unions
- downstream industries

The mission of this group is to develop a clear, measurable and agreed longer-term vision for the European chemical industry based on the Cefic Scenarios 2015.

5. Summary and Conclusions

The chemical industry has demonstrated that futuring is not only possible at the level of a specific company [20] but also with industry-wide initiatives. Obviously, this becomes all the more difficult the more companies and countries have to be involved, but there are tools and concepts available (e. g. Think Tools® methodology) which can help in the management of even such complex futuring processes.

Comparing the different initiatives, one issue shows up very prominently: innovation.

In all 3 European futuring concepts, innovation is identified as one of the most important drivers for the positive future development of the chemical industry. In contrast to the US concept "Technology Vision 2020", innovation is not only

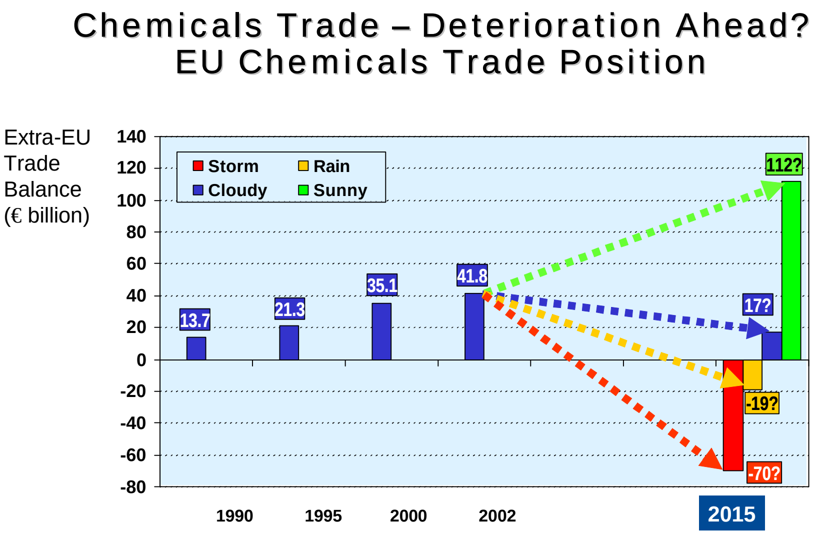

Figure 12: Chemicals trade balance (source: CEFIC)

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limited to scientific and technological results[5] but, in a much broader sense, it includes business process innovation, new business models, improvements in supply chain management etc. In all three European futuring initiatives, the people factor is mentioned and related on the one hand with the challenges of knowledge and skills and on the other hand with the risk of brain drain and an eroding knowledge base. But only in the UK concept is a clear action plan already visible with the establishment of a skills network. And even there the unanimous realization that customer orientation and marketing & sales knowledge has to be improved has, up until now, not led to any concrete action.

While action and clear measures are the strength of the UK concept, the strength of the Cefic concept is that it clearly addresses the challenges the chemical industry is facing, including the increasing regulatory burden. It even quantifies the consequences if not enough is done by the authorities and the industry itself. While in the UK concerted action between government and industry is noticeable, in order to defend and improve the competitiveness of the chemical industry, this has still to be achieved at the European level. The establishment of a Chemical Advisory Networking Group for Europe is the right and first step in this direction, with the UK concept as the benchmark.

6. References

[1] Cornish, E. (2004) Futuring: *The Exploration of the Future*, World Future Society, Bethesda, Maryland, USA.

[2] Spitz, P.H. (2003): *The Chemical industry at the Millennium. Maturity, Restructuring and Globalization*, Philadelphia, Penn. Chemical Heritage Press.

[3] Cefic (2004) *Chemical industry 2015: Roads to the Future*, Final Report Cefic, Brussels, Belgium.

[4] Chemicals Innovation and Growth Team (2002) *Enhancing the competitiveness and sustainability of the UK chemicals industry*, Department of Trade and Industry (DTI), London, UK.

[5] Heinzelbecker, K. (2001) *The Future of the Chemical industry*: ECMSA Scenarios 2010, ECMSA Conference, Berlin, Germany.

[6] The American Chemical Society (1996) *Technology Vision 2020 for the future of the US chemical industry*, Washington, USA.

[7] www.chemicalvision2020.org/techroad maps.html

[8] Procter, D. (2004) : *The future of the chemical industry - the challenges and opportunities ahead for the U. S. chemical market*. July 8, 2004, www.philamixers.com

[9] Grote, B. (2002) Chairman's Foreword, *Enhancing the competitiveness and sustainability of the UK chemicals industry*, DTI, London, UK.

[10] *Chemicals Innovation and Growth Team* (2002) Executive Summary. www.dti.gov.uk

[11] *Chemicals Innovation and Growth Team* (2002) Final Report, www.dti.gov.uk

[12] Forum for the Future (2002) *The Sustainability of the Chemical industry*, 19-26, www.forumforethefuture.org.uk

[13] Harrison, C. (2003) *Innovation in the UK Chemicals Industry : The work of the Chemistry Leadership Council*. Dicida-UK conference paper Grimsly.

[14] www.cogent-ssc.com

[15] Heinzelbecker, K./Gronych, R. (1995): *Scenario 2010. Challenger Asia*. Economic Bulletin, Cefic Brussels, www.cefic.be/activities/eco/ecobul/Eb 9511b.htm

[16] Fondazione Rosselli (2003) FuTMaN: *The Future of Manufacturing in Europe 2015-2020. The challenge for sustainability*. Final Report for the European Commission. Directorate-General Joint Research Center

[5] The value of looking at Science and Technology not only from a chemicals perspective and analyzing its impact on the society and businesses is best demonstrated in [21].

[17] Roveda, C./Vercesi, P (2002) FutMan: *Case Sector Report Basic Industrial Chemicals*, europa.eu.int/…/industrial_technologies/pdf/pro-futman-doc8.

[18] Rammer, Ch. (2003): *The Chemical industry as Driver for Innovation in other Industries*. In: M. Droescher, G. Festel,, M. Jager, The Power of Innovations, How Innovations can Electricize the Chemical industry, Aachen, 50-66.

[19] Chem. System (1998): *Industrial Restructuring in the Chemical industry*. Final report prepared for the European Commission DG III-C-4.

[20] Mannerma, M. (2004): *Traps in Futures Thinking - and how to overcome them*. In: Thinking Creative by in Turbulent Times (Ed.: Didsbury Jr. H) World Future Society, Bethesda, Maryland USA, 50-51.

[21] Coates, J. F./Mahaffie, J. B./Hines, A. (1997): *2025. Scenarios of U.S. and Global Society*. Reshaped by Science and Technology. Grennsboro, Oakhill Press. USA.

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