THE CHEMICAL INDUSTRY 2000

The International Chemical Industry and the Israeli Chemical Industry Potential for Future Growth

Ephraim Kehat ● Reuven Wachs

Technion - Israel Institute of Technology
The Samuel Neaman Institute
for Advanced Studies in Science
and Technology

The Ministry of Industry and Trade
Chemicals and Minerals Administration
The Manufacturers' Association of Israel
Chemicals and Pharmaceuticals Div.

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תמונת השער: המתקן לחומצה גופרתית ברותם דשנים.

התמונה באדיבות כ.י.ל. - יחסי ציבור

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By

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and

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With support from

The Ministry of Industry and Trade, Chemicals and Mineral Administration
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תקציר

מחקר זה מומן ע"י מוסד נאמן, משרד התעשיה והתאחדות התעשיינים ובוצע ע"י אנג' ראובן וקס ופרופ' אפרים קחת.

שלב א' של המחקר אשר פורסם בדצמבר 1993 סכם את הקורה בשני העשורים האחרונים בתעשיה הכימית בעולם ובתעשיה הכימית בישראל:

התעשיה הכימית במערב לא צמחה בשנים האחרונות. הדאגות בגלל הנסיגה הכלכלית בשנים האחרונות עכבו את ההכרה כי מקור אי הצמיחה הוא מבני. מגוון הפתרונות שנוסו ע"י החברות בתעשיה הכימית כדי לשפר את ההחזר למשקיעים כגון: הורדת עלויות, קיצוץ מספר העובדים, מכירת וסגירת מפעלים, מכירת מפעלים לעובדים, מיזוגים, רכישות חברות, הגדלת יצור, כניסה למוצרים בעלי ערך גבוה יותר, חיזוק פעילות בחו"ל, חלוקת החברה וריארגון יסודי, לא הראו בסיכום שפור בולט ברוחיות או בגידול לרב החברות.

התעשיה הכימית במזרח אסיה עברה גידול מהיר יותר מאשר התעשיה הכימית במערב. קצב התפתחות התעשיה הכימית בישראל היה בין קצב ההתפתחות האיטית של התעשיה הכימית במערב לקצב התפתחות המואצת של התעשיה הכימית במזרח אסיה, וגדל במיוחד מאז 1989 . הגידול הריאלי הממוצע של התעשיה הכימית בישראל היה 2.4 % ב 1979-85 ו 4.9% ב 1985-92

הערך המוסף בתוך מחיר מוצרי התעשיה הכימית בישראל הוא נמוך, יחסית למדינות אחרות, בגלל רמה נמוכה של אינטגרציה. השוק החקלאי דומיננטי ביצוא של מוצרי התעשיה הכימית בישראל (56% מכל היצוא הכימי, להוציא מוצרי נפט).

שלב ב' של המחקר אשר פורסם בנובמבר 1994 תאר את ההתחבטויות בתעשיה הכימית בעולם ובמיוחד בארה"ב לגבי כיווני ואסטרטגית החברות בעתיד והביא תאורים של מגזרי שוק המתפתחים מהר ואשר כדאי לתעשיה הכימית בישראל למקד בהם פעילות.

מגזרים אלה קובצו בשלוש קבוצות:

א. מוצרי בינים שאינם מיוצרים ביום בישראל ואשר יש סיכוי שיתקיימו תנאים מתאימים ליצורם בשנים הקרובות, כגון: גז סינתזה ומתנול, תולדות גפרית, תולדות אתילן, פרופילן,, C4 בנזן, קסילן וכלור.

ב. מוצרים מתוחכמים הדורשים ידע ספציפי ולווי צמוד של שרות ללקוחות, כגון: חמרים מונעי שריפה, קטליזטורים, תוספות למוצרי מזון, חמרים קרמיים מתקדמים, חמרים פלסטיים מתקדמים, חמרים מרוכבים, תרופות ודטרגנטים חדשים.

ג. טכנולוגיות חדשות בהן יהיה יתרון לחדשנות כגון: טכנולוגיות להגנת הסביבה וטיהורה, שחרור מבוקר של תרופות ודשנים, על מוליכים בטמפרטורות גבוהות, ממברנות, תחומים מסוימים בביוטכנולוגיה, יצור לפי הזמנה, פעילות בתנאים על-קריטיים, וכימיה של אוזון, ציאנידים והלוגנציה.

בסיום העבודה מובאות המלצות כלליות שהחשובות בהן הן:

המשך פיתוח התעשיה הכימית בישראל דורש שיושם דגש על מקצוענות העובדים בתעשיה ועל חדשנות אשר תאפשר פריצה לשווקים חדשים.

התעשיה הכימית בעולם אינה מוגבלת בגבולות מדינות ועל התעשיה הישראלית להתרגל לחשוב לפעול לא רק ביצואן אלא גם ביצרן עולמי ולחפש אפשרויות נוספות לשיתוף פעולה עם חברות זרות.

התמיכה הממשלתית בתעשיה צריכה להתרכז בשיפור התשתית, דהיינו: כבישים, רכבת, מים, חשמל, תקשורת והכשרת כח אדם מקצועי באמצעות חינוך טכנולוגי תיכוני וגבוה, במקום לתת תמיכה ישירה ברווחיות החברות. התמיכה הממשלתית במחקר צריכה להתחלק בסיכון, אבל לא לקחת את כל הסיכון.

חוברת זו המאחדת את הדוחות הקודמים בתוספת תיקונים ושיפורים מוקדשת לזכרו של **אלי קרן**, אשר רכז את ועדת ההיגוי בתחילת עבודה זו.

ABSTRACT

The Western chemical industry has been stagnating for many years. The concern over the recent depression delayed the recognition of this structural stagnation.

Data for the past two decades are presented, and correlated with other recorded parameters. Some long term trends are analyzed.

The performance of several large international companies is described, and the apparent unique characteristics of their strategy are presented.

The variety of strategies used by the chemical industry in order to improve the return to investors, such as cutting costs, staff reductions, divestitures, leveraged Buy-outs, mergers and acquisitions, strengthening existing production, move into higher added-value products, increased foreign trade and production, diversification, demergers and reengineering did not result in significant improvements of the profitability or the growth rate for most companies.

The chemical industry in the Pacific Rim countries has undergone faster expansion than the Western chemical industry.

The performance of the Israeli chemical industry has taken an intermediate path between the slowed-down Western rate of growth and the impressive growth rate in the Pacific Rim, specially after 1989. The average yearly real growth rate of the Israeli chemical industry was 2.4% for 1979 to 1985 and 4.9% in 1985 to 1992. However, the increment of the added value in the total value of the chemical shipments is low in Israel relative to other countries, due to a rather low level of integration. Another element of both strength and weakness of the Israeli chemical industry is the dominance of the agricultural market in the exports of the industry.

Comparison of the relative size of the chemical industry and its added value with those of the developed countries showed that there exists a potential for growth.

We have identified market segments that are growing faster than other segments of the chemical industry. These were presented in 3 groups of potential areas for growth for the Israeli chemical industry:

1. Families of intermediates: Synthesis gas and methanol, sulfur derivatives, chlorine derivatives and derivatives of ethylene, propylene, C4, benzene and xylene.

2. Specialties that require specific knowhow and close service to the clients, such as: Flame retardants, catalysts, food additives, advanced ceramics, advanced plastics, composites, drugs and detergents.

3. New technologies with advantages for innovation, such as: Environment control, controlled release, superconductors, membranes, biotechnology, custom manufacture, ozone chemistry, halogenation, cyanide chemistry and supercritical technology.

The general strategy of the chemical companies should be to build core competencies, invent and innovate, keep an open mind, support professionalism and training of personnel, and continually seek new opportunities, operation and cooperation abroad.

Government support should be for improvement of the infrastructure, such as roads, railroads, water, electricity, communication, and training of competent technical, engineering and management personnel. Government support of research should share risks but not undertake all the risks.

אלי קרן ז״ל

חוברת זו מוקדשת לזכרו של אלי קרן ז״ל, אשר שימש כיו״ר ועדת ההיגוי למחקר זה על התעשיה הכימית, עתידה והשתלבותה בכלכלה העולמית.

אלי קרן נולד ב-13.9.35 בישראל ולצערנו לא ראה את פרי יוזמתו, מאחר שנפטר ב-16.12.93, לפני סיום העבודה, ולכן מצאנו לנכון להקדיש חוברת זו לזכרו.

אלי קרן ז״ל הינו בוגר הטכניון בהנדסה כימית משנת 1960 ובעל תואר שני בהנדסת מחצבים בטכניון.

משנת 1960 ועד 1988 עבר בועדה לאנרגיה אטומית כמנהל מו״פ בקריה למחקר גרעיני, ולאחר מכן כמנהל מו״פ של מינהל הועדה לאנרגיה אטומית. בתפקיד זה מילא משימות בטחוניות חשובות.

ב-1988 עבר לכי״ל ושימש כסמנכ״ל למחקר ופיתוח, ומנהל חברות בנות וכן היה יו״ר דירקטוריונים של חברות בנות של כי״ל.

אלי קרן מילא תפקידים רבים בהתנדבות במסגרת המחלקה לפיתוח הנגב של הסוכנות היהודית. עסק בהקמת ״חממות״ למדענים עולים חדשים. נושא פיתוח התעשיה בנגב היה בראש מעייניו בשנים האחרונות.

השאיר אחריו אשה ושלושה ילדים, שניים מהם עוסקים בתעשיה הכימית בנגב.

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1. INTRODUCTION

1.1 Objectives

The objective of this study is to identify promising directions for the development of the Israeli chemical industry in the context of the international chemical industry.

The methodology employed is:

1. A study of the characteristics of the international chemical industry and a more detailed look at a few large chemical companies.

2. A study of the characteristics of the Israeli chemical industry.

3. Identification of the industry segments with a high potential for development.

4. Proposals for strategies and directions for the development of the Israeli chemical industry.

1.2 The Chemical Industry

The chemical industry has a number of unique characteristics:

The raw materials it uses are important for their chemical properties rather than for their physical or mechanical properties.

It transforms chemicals into other chemicals with a high added value. The transformation may be by made raising the concentration of the main product or by lowering the concentration of impurities, by employing one or more chemical reactions, or by a combination of all the above.

It uses sophisticated equipment, and advanced production, control, and quality control methods.

The investment per employee and the productivity per employee are high, and therefore, highly trained persons must be employed.

In the period of 1984 to 1987, the chemical industry in Western countries underwent considerable restructuring, caused mainly by overcapacity in the production of chemical commodities, and increased construction of chemical commodities plants by oil producing countries of the third world.

This restructuring included closure of older and less efficient plants, exchange of assets between companies in order to increase market share in preferred markets, buying smaller companies, particularly "specialties" companies, purchasing their own shares, in order to boost their stock market value, retiring older employees and firing other employees, overall reducing manpower by about 15%, reducing R&D in commodities and increasing R&D in emerging fields, particularly in biotechnology.

Since most of the combinations of these restructuring efforts did not increase the profitability of most of the companies in the long term, a second round of restructuring was started in 1991 and continued through 1993. In this round a further reduction of manpower was the dominant feature, but it included more exchange of assets and combined ventures with other companies, changes in management structures, and reduction of the involvement in some of areas in which the companies had invested heavily in the previous decade.

1.3 The Israeli Chemical Industry

The Israeli chemical industry transforms the few local raw materials (Dead Sea brines that include potassium, magnesium, chloride, and bromide ions, and low concentration phosphates), and imported raw materials and intermediates into higher value products.

The Israeli chemical industry is characterized by considerable government involvement as do the Italian and the French chemical industries.

This involvement takes the forms of ownership of major parts of the industry, support for investment and R&D, and price controls, particularly for fertilizers for the internal market (unlike dumping, the internal prices are often lower than the export prices).

Other specific characteristics of the Israeli chemical industry are: Political, instead of professional considerations in the appointment of the higher levels of management, control of wages by the government and the Union, interference of the Union in management decisions, and practically no R&D in small and medium sized companies.

The general market crisis in the eighties combined in Israel with very high debt that was the results of high interest rates at the height of the high inflation period. The restructuring of the Israeli chemical industry resulted in some reduction in manpower, However, government and Union interests did not permit massive manpower reductions or closure of inefficient plants.

The government decided to sell the government industrial companies, but the politicians managed to delay the implementation. The financial crisis of the Union's industrial complex did not permit continued investment in the Union's chemical companies for the duration of the crisis.

In the next 3 chapters the global chemical industry and the Israeli chemical industry will be discussed in more detail.

2. The Chemical industry

2.1 Definitions of the Chemical Industry

There are many definitions of the chemical industry, and it was necessary to agree on a consistent set of definitions at the start of this study.

A useful comparison of the most used definitions is given by Kline (128). He shows that there are at least two definitions of "Industrial Chemicals" and in addition definitions of "Chemical and Allied Products," and "Chemical Products". The more comprehensive definition: "Chemical Process industries (CPI)" includes industrial chemicals, the food industry, rubber and plastic products and additional products, utilizing chemical processes for their production.

The definition of the Chemical Process Industries, as used by Chemical Week is (129): "CPI includes Chemical and Allied Products, pulp, paper and paperboard, processing of petroleum and natural gas, rubber and plastic products, products of stone, clay and glass, primary non-ferrous metals, sugar refining, wet corn milling and similar processing of food and beverages, textile dying and finishing, leather tanning, dry cell & storage batteries, semiconducting materials, carbon and graphite products, hard surface floor covering."

There is no accepted definition of CPI in Israel, but it can be constructed using the usual classification, by combining the categories (130):

10	Mining and quarrying
11,12	Food and beverages
132	Synthetic fibers
150	Leather tanning
17	Paper and paper products
19	Rubber and plastic products
21	Non-metal minerals
20	Chemical industry
222	Non-ferrous metals

The statistical publications of the United Nations statistics (132) use the ISIC code, of which categories 351 and 352 roughly correspond to the definition of Chemical and Allied Products:

351 Basic industrial chemicals (including fertilizers, pesticides and synthetic fibers).
352 Other chemicals (including paints, varnishes, soap and toiletries, drugs and medicines).

We have used for this study the American definition of Chemical and Allied Products consists of the following categories:

281 Industrial Chemicals.
282 Polymers.
283 to 287 and 289: Other Chemicals and Allied Products.

This list includes:
Pharmaceuticals, detergents, servicing materials, polishing preparations, toiletries, cosmetics, paints, coatings, fertilizers, printing inks, carbon black, adhesives, additives, catalysts, industrial chemicals and synthetic materials.

For the Israeli data we have used category 20 used by the Ministry of Industry that includes:

200 Basic Chemicals
201 Pharmaceuticals
202 Soap and cleaning agents
203 Cosmetics
204 Paints and Lacquers
205 Pesticides and Disinfectants
206, 208 Other chemicals (including petroleum distillates)

However, potash and phosphate rock are listed under category 10, (mining and quarrying), and were included in the definition of the Israeli chemical industry in this report.

2.2 Scope

2.2.1 Size and share

The chemical industry is the supplier of materials for other industries and for other segments of the economy, including agriculture, plastics, textile, metallurgical and pharmaceutical industries. The chemical industry supplies performance chemicals for high tech industries such as the electronics, and the modern ceramics industries. Consumer and household goods are also supplied by the chemical industry. Other products of the chemical industry are: food additives, explosives, propellants, etc.

Historically, whenever the supply of natural materials for some particular need became limited, and the technological basis for production of the missing materials was attainable, the chemical industry managed to supply the materials and to enable the downstream industry to develop. This was the basis of the explosive development of the chemical industry, the establishment of the synthetic dyes and drugs industries in the mid-nineteenth century, and the the establishment of the pesticides and polymers for plastics and fibers industries in the mid-twentieth century.

The performance of the chemical industry in the world (based of the value of shipments) in 1991 is shown in Table 1.

TABLE 1
The chemical industry in various countries
Sales in 1991 (136,138,143)

Country	Sales $MMM
USA	287.5
Japan	180.0
Germany	100.0
France	66.1
UK	51.0
Italy	50.3
Spain	38.4
Belgium	27.9
Netherlands	24.3
Switzerland	15.4
China	40.0
Singapore	3.0
S. Korea	20.0
Taiwan	
Israel	**7.0**

The share of the chemical industry in the value of the total manufacturing varies in different countries between 8 and 14%, a rather high fraction.

Neglecting the values of the inputs to the chemical processes causes some distortion of the numbers when calculating the share of the value of shipments of the chemical industry in the total economy, since many chemical products go through interim stages of processing a number of times on their way to the final consumer product. The price of the raw materials will influence the value of the shipment, causing a bias in comparison with products that use cheaper raw materials. These two possible distortions are avoided if the data are presented in the form of added value accounting, which deducts from the value of shipments the value of the raw materials, and other purchased values used for the production.

The ratio of the added value of chemicals relative to the added value of all manufactured goods ranges from 8.3% to 15.2% as can be seen in Table 2.

The share of the chemical added value in the total added value of manufactured goods is fairly constant in the world, and is rather similar to the share of the value of the chemical shipments in the total value of manufactured products. This might suggest that there is no real need to differentiate between those two indicators.

However, when the ratio of the chemical added value to the value of chemical shipments for each of the countries in Table 2 is calculated, some interesting differentiations can be seen in Table 3:

TABLE 2
The share of added value of the chemical industry in the total manufacturing added value (132,133).

Country	Total Manufacturing added value $MMM	Total chemicals added value $MMM	Ratio of added value of chemicals to total mfg added value	Year of data
USA	1308	156	11.9	1989
Japan	872	87	9.9	1989
Germany	427	56	13.1	1989
France	204	22	11.1	1991
UK	180	22	12.2	1990
Italy	112	17	15.2	1991
China	111	14	12.6	1989
Spain	66	9	13.6	1991
S. Korea	66	6	9.1	1988
Switzerland	57	9	15.8	1990
Netherlands	54	7	13.0	1990
Belgium	33	6	18.2	1991
Denmark	19	2	10.5	1991
Singapore	12	1	8.3	1990
Israel	9	1	11.1	1988

The countries can be grouped by the added values:

1. A group with 40-60% ratio, consisting of USA, Germany, UK, Denmark, Switzerland and Japan.

2. A group with 30-40% ratio that includes France, China Italy, South Korea, and Singapore.

3. A group with 15-30% ratio that includes Spain, Belgium, Israel and the Netherlands

The higher values indicate a developed industry, vertically integrated, which starts from cheap raw materials and accumulates added value on its way to the consumer products. Sales of raw materials and one-step products tend to lower the value of this indicator and the chemical industry contributes less to the national economy, even though the share of the value of shipments is high. Therefore, the weight of the American chemical industry in the US with a 9% value of total shipments share (138), is greater than, for instance, that of Israeli chemical industry, with a shipments share of 14% (Table 19).

TABLE 3
The share of added value in the shipment value of chemicals (132,133,138)

Country	Chemicals added value $MMM	Chemical shipments $MMM	Ratio of added value to shipments (%)
USA	156	288	54
Japan	87	180	48
Germany	56	100	56
France	22	66	33
UK	22	51	43
Italy	17	50	34
China	14	40	35
Spain	9	40	23
Switzerland	9	16	56
S. Korea	6	20	30
Netherlands	7	24	29
Belgium	6	29	21
Denmark	2	4	50
Singapore	1	3	33
Israel	1	4	25

In any case, the importance of chemical industry in the world, specially in the countries of the first group, cannot be overestimated. It should be also noted, that the fast developing South-Asian countries are better placed in this classification, than some of the developed European countries (and Israel).

2.2.2 The International Character

The international character of the chemical industry is shown in Table 4:

Two of these companies have more foreign assets than local assets and 7 of the 8 companies have 45% or more foreign employees.

TABLE 4
The largest transnational chemical corporations
(1990 figures)(158)

Company	Position in global top 50 List in 1992	Foreign Assets $MMM	%	Foreign Employment	%
DuPont	5	16.0	41	36,400	29
Bayer	4	14.2	56	80,000	47
Rhone-Poulenc	9	13.0	61	50,525	55
Hoechst	2			82,169	48
Ciba	10			69,702	74
Dow	6	10.9	45	28,612	46
ICI	3	10.5	18	78,400	59
Solvay	15	8.1	91	36,578	80

2.2.3 Rate of growth

The rate of growth is one of the most important indicators describing industrial activity. It is high when the industry finds new applications, provides answers to new or expanding demands of the economy, and supplies to downstream industrial segments that are in the stage of youthful development. It is low when the industry supplies more of the same, following only the growth of population.

The chemical industry up to 1973, used to lead in fast industrial development, even when it was sometimes accompanied by a drop in profitability (134). The rate of growth of the chemical industry was in the neighborhood of 9% for many years, triple the rate of the general industrial average. For several segments, like polymers, and pesticides, a rate of growth of 15% per year was not unusual (136).

The 1973 crisis that was highlighted by the sharp rise in the price of crude oil, which had not been predicted by any of the best analysts of the chemical industry since they customarily, used extrapolations of the prevailing current prices and production rates.

The change in the rate of growth of the chemical industry was not caused solely by the energy crisis of the 1973, but was also caused by a structural change, some signs of which could have been detected earlier (135).

Soon after 1973 the average rate of growth of the chemical industry dropped to 6%, and later dropped further to the range of 3% per year, loosing totally the advantage over the overall industrial growth rate. (see Figure 2 in chapter 3.3.1)

Since this phenomenon was fairly general for all the industrialized world and since it did not change appreciably for almost two decades, the reasonable conclusion seemed to be that the situation is a consequence of the maturity of the chemical industry, and not very much can be done about it. Today, this complacency may be questioned since the rate of growth in the developing countries of the Pacific Rim is over 10% per year, and the excuse of cheap labor does not apply to a capital intensive industry like the chemical industry.

China also joined the fast rate growth countries. Its economic lag is still enormous, but the shear dimensions of this country mean, that a small change will be of a critical importance on a world scale.

Not all countries have followed the pattern of the Western countries. In Israel, although we also had the characteristic drop of the rate of growth in the seventies, the recent growth rate of 5 - 7% per year, is almost double that of the Western countries. It is important to understand the reasons for this development, in order to be able to predict if it is a stable pattern, or a transient event.

2.3 Trends

2.3.1 Maturity

The maturity of an industry, characterized mainly by a low rate of development and a reluctance to long term projects and technological innovations, results when its expansion is no longer driven by new and growing applications and when its technological strength is nearly exhausted. The maturity of a consumer industry is easily discernible. However the chemical industry sells mainly to industrial customers or to agriculture enterprises. The degree of maturity of these customers is reflected in the rate of growth of the supplying chemical industry, and the analysis of the sales targets may be of primary importance. Specifically, a few of the major markets of the chemical industry, such as car production, tire production, home construction, and traditional agriculture in the Western countries have the characteristics of mature industries.

Since such an analysis results in the former conclusions, it is unlikely that a mature industry (chemical or non-chemical) will show an initiative for a major change in its market orientation, without an additional external stimulus.

J. Beckman wrote in 1969 (134):
"The chemical industry has been among the largest investors in R&D. These expenditures have resulted in a flow of new products and processes that have made significant contributions to the above average growth of the chemical industry and to major changes in its product mix over the years. Synthetic fibers, plastics, gases, synthetic rubbers and many other products have been developed and expanded in relative importance. Change is the important constant in this industry. For example, Stauffer Chemical estimated that one third of its sales in 1968 was in products added during the preceding five to ten years.

The rapid rate of innovation has had dramatic impacts on competitive patterns within the industry, has created enormous investment requirements and opportunities, and has fed on itself by stimulating an intensification of research efforts by many companies in order to remain competitive. It also has contributed importantly to making chemicals one of the great growth industries in the United States."

Twenty years later D. Garrett wrote (137):
"The chemical industry was very large, with generally slowly rising sales, and steady or declining profits until 1986. Its reinvestment in new capital equipment has been modest, its environmental spending heavy, and its R&D spending not very aggressive, at least compared to its foreign competition. It has become a large and diversified, but mature industry that still has an excellent positive trade balance, but is increasingly having difficulty meeting worldwide competition. It would appear to be in the decision period of its history between allowing a conservative, non-technical or long-range thinking management letting it become slowly more obsolete and noncompetitive (like the steel industry), or continuing to be a more aggressive industry investing in new innovations, processes, and equipment, as a large net exporter".

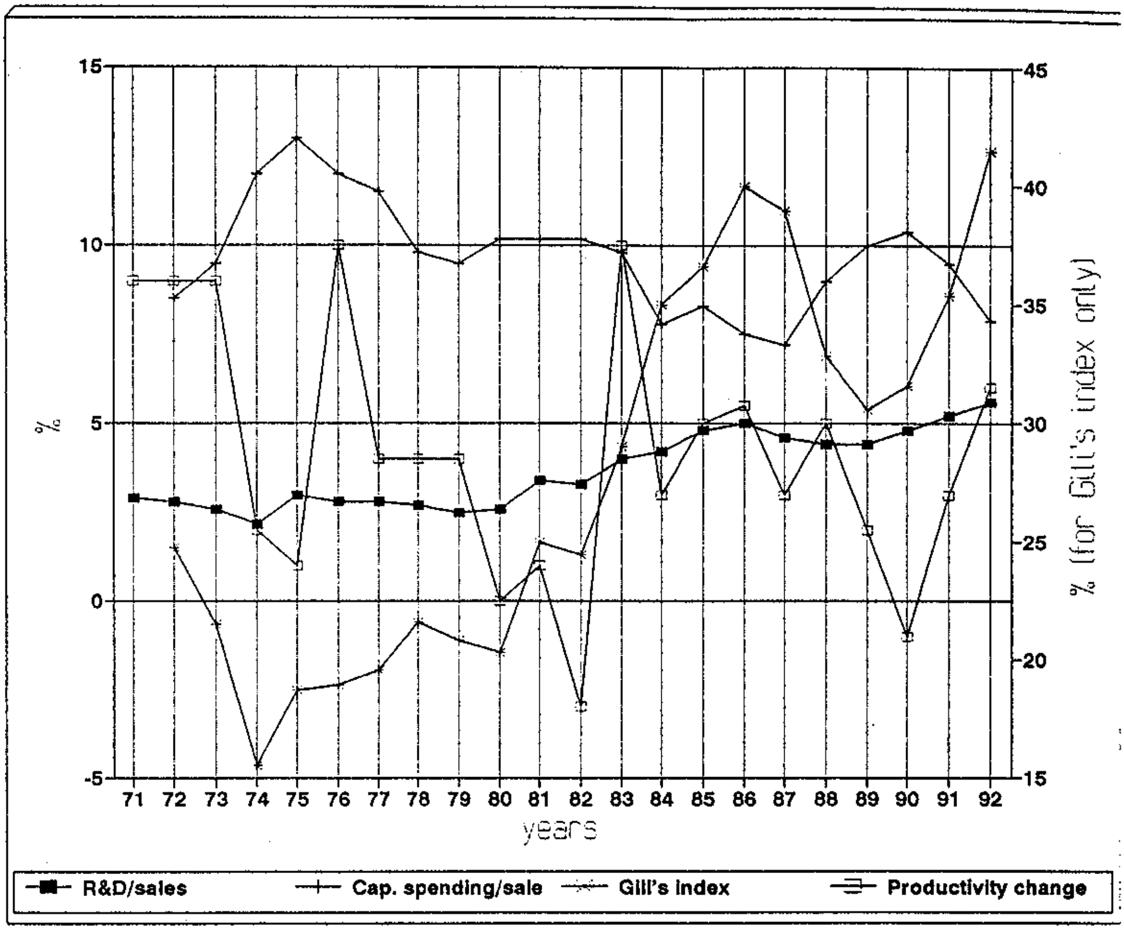
2.3.2 New technologies

One of the signs of maturity reached by a particular industry is the relative maturity of technologies it uses. The chemical industry was, a long time the leader in modern technologies, like catalysis, polymerization, and the chemical engineering disciplines, driven by the oil and petrochemical producers. However, fast technological expansion and the economy of scale led to over capacity, and this in turn led to technological slow-down. In this respect very little has changed during the past 30 years. A few new significant demands for new materials by dynamic young markets, such as the chemicals for electronics, or ecological demands for new separation technologies and better purification methods gave drive to the development of new products and technologies, but their overall impact on the industry was minor.

2.3.3 Research and development

After a long period of decline, the chemical industry seems to be trying to spend more on R&D, but R&D has not increased significantly relative to sales, despite governmental encouragement (Fig 1).
However, the values in excess of 5%, shown for the USA, are very high in comparison to the average of 1.5%, characteristic for Israel.

FIGURE 1: The various factors which may influence the performance of the chemical industry in the USA (138).



The reaction to the 1973 crisis was to increase investment and decrease R&D. From 1975 to 1987 capital investment decreased, then rose till 1990, when it started to decrease again. R&D expenditures rose slightly and almost steadily from 1975. The Gili factor in Figure 1 is an indicator suggested by Dr. G. Fortuna (showing the share of R&D to the sum of R&D plus the capital investment). The Gili factor rose over the 1974 to 1993 period, with two dips in 1982 from 1989 to 1991. (The data for R&D and capital spending represents only the major corporations).

2.3.4 Profitability

The chemical industry of the industrialized countries is not very profitable. Historically, the situation was different, and the chemical industry was among the most profitable segments of the industry. Backman (134) shows the drop of the profitability during the period of 1956 - 1968 for the pretax margins on chemicals in the USA:

TABLE 5
The pretax profitability of the chemical industry in the U.S. (134).

Year	Pretax Profitability %
1956	18.2
1957	17.4
1958	13.5
1959	17.5
1960	15.0
1961	14.6
1962	15.4
1963	15.3
1964	15.2
1965	14.4
1966	13.6
1967	11.0
1968	11.1

Later developments for a few companies can be seen in Figure 6, but in recent years the average net profit was less than 10%. In the USA, there was a slight improvement around 1989, and then the average profits plummeted again, to under 5%. The other western countries followed a similar trend.

Many explanations were suggested for this phenomenon: over capacity and exhaustion of the economy of scale. Berenson (139) suggested heavy competition as the reason. He points out that the chemical industry faces five types of competition:

1. Inter company competition
2. Inter commodity competition
3. Inter process competition
4. Inter industry competition
5. International competition

Achilladelis et. al. (140) discuss this pattern of profitability, and explain it as due to the maturity of the industry.

It is often stated, that various segments of chemical industry have different levels of profitability. For instance, fertilizers are assumed to have a profit level of about 2%, and pharmaceuticals of 15%. These numbers are inexact. Even the pharmaceutical industry, which is known to overprice its proprietary products, shows a rather mixed picture, and a few fertilizers companies are very profitable.

Table 6 shows the composite profit margins by chemical industry segment (as % of turnover) for the USA for the relatively profitable years of 1990 -1991.

TABLE 6
USA composite net profit margins by chemical industry segment (as % of turnover for 1990 & 1991) (141)

Segment	Profit margin 1990 %	Profit margin 1991 %
Industrial chemicals	5.8	3.8
Specialty chemicals	8.7	7.7
Biotechnology	-20	-9
Fertilizers	8.6	7.0
Paints	4.8	3.9
Oil processing	3.9	3.3
Pharmaceuticals	13.8	14.9
Detergents	6.6	5.6

The profits in pharmaceuticals were high, and showed the only rise in 1991.

A recent study to find a common factor in profitability of pesticides (142) did not find any common factor in overall performance or in R&D expenditures, or in sales. The only grouping found was geographical (Table 7).

It is probable that beyond the drop of profits, caused by competition, the profits of companies are controlled mainly by the management skills. One of the most important of these skills is the management of continuous change, not a common ability in a mature industry.

There is no reason to believe that the profitability of the chemical industry in the Western countries will change, unless the maturity syndrome is relaxed.

TABLE 7
Pesticide producer profitability in 1992 (142).

Company	Profitability (from sales) Range	Rank	Sales $MM	Sales Rank
DuPont		1	1955	2
American-Cyanamid		2	1000	10
Dow Elanco	15%-20%	3	1581	7
Monsanto		4	1647	6
FMC		5	455	14
Sandoz	10%-15%	6	841	11
Ciba		7	2831	1
Rhone-Poulenc		8	1842	4
Zeneca	5%-10%	9	1716	5
Shell		10	725	13
Bayer		11	1869	3
Sumitomo		12	417	15
BASF	<5%	13	1142	9
Schering		14	788	12
Hoechst		15	1333	8

2.3.5 The remedies tried

The structural changes in the chemical industry started in the seventies but were recognized as such much later. Wei (145) who studied the structure of the process industries in 1979, did not foresee any slow-down of the growth rate. Bower (135) in 1986, Achilladelis (140) in 1988, Garrett (137) in 1989, and the study "Made in America" by the MIT Commission on Industrial Productivity (144) in 1989 recognized the structural change.

The remedies, as listed by Garrett (137), are as follows:

1. Cutting costs.

This was possible, since many chemical operations acquired by oil companies were poorly managed. Changing managements and/or ownership and reorganization, sometimes led to lower costs.

2. Staff reductions.

In several cases the massive lay-offs were beneficiary for the companies, but in other cases the engineering, technical or R&D staffs were first to be fired, causing severe long term damage to the company. Luberoff cited the Investors' Business Daily (146): "Fewer than one half the outfits that tried downsizing succeeded in increasing profitability. In addition to the poor souls who were laid off."
Table 8 shows some of the saddest results:

TABLE 8
Effect of restructuring on return on equity (146).

Company	Return on equity Before %	After %
Eastman-Kodak	12.9	4.5
Zenith-Electronics	8.1	-32.0
Sears-Roebuck	10.8	-2.3
Westinghouse	18.9	9.8
American-Express	15.1	7.1

3. Divestitures.

This went beyond closure or sale of many inefficient units. In the mid-80s it became almost an obsession, and very large numbers of divisions from many companies were divested. Sometimes it led to a loss of valuable know-how, in many cases going abroad. One of the theories, supported by the team from MIT, was that the chemical companies have to divest the commodities, and to remain with higher added value products, called "specialties". Forgetting that commodities ere the cash cows of the corporations proved to be a mistake.
The divestitures employed by American Cyanamid, Ethyl and Eastman Kodak (4) in the 1990s were to spin off chemical units and to focus on what they think they do best: drugs, petroleum additives, and imaging products respectively.

4. Leveraged Buy-outs.

The buyers of plants under this scheme were a combination of people who worked in the plant with financial backing by financial organizations. Such people were more highly motivated than the corporate buyers, and, therefore, the chances for success were higher. There have not been enough studies to tell if this scheme works in the long run, or whether it results in the control by the financial groups and the birth of a classic corporation.

5. Mergers and acquisitions.

In the mid 1980s acquisitions (as well as divestitures) became almost epidemic.

Many mergers and acquisitions were made. Those that increased market share were often successful. However, some appeared to be based on deals meant more to show financial acumen and improve the position of the company in the stock market rather than in the chemicals market. For instance, Cheseborough-Pond took over Stauffer Chemicals in 1985, was later acquired itself by Unilever, the British - Dutch consumer products giant for $3.1 billions. Unilever then sold the Stauffer operation (in 1987) to ICI for $ 1.7 billions, which in turn sold Stauffer's specialty chemical division to Akzo America for $625 millions, and the basic chemical groups to Rhone-Poulenc for $522 millions It is not known who did profit from this chain of transactions, but it did not improve the motivation of Stauffer employees towards more efficient production. Garrett commented: "Mergers would appear to be a poor substitute for internal development if management pursues strictly one path or the other, or has no intention of capitalizing on new technical developments"

6. Strengthening existing production.

Commercial activities, economy of scale (when possible), operating and managerial efforts, technical innovations and acquiring new technical skills by buying smaller outfits. The United States has always excelled in the technical improvements, but recently take-overs were taking the place of innovations, particularly in the pharmaceutical business.

7. Move into higher added-value products.

This much advocated approach in the middle eighties now has many critics. Many introduced specialties serve other mature industries, like oil drilling or textiles and their behavior follows that of commodities. A differentiation between industrial specialties and consumer specialties can be useful, particularly if based on forward integration.

8. Foreign trade and production

This has been a useful approach for the USA, and resulted in a strong surplus in foreign chemical trade balance. However, this surplus was sharply reduced when their main trading partners in Europe went into recession.

9. Diversification

A much recommended approach that showed positive results in many cases, by spreading the risks and balancing seasonally sensitive products. Occasionally it meant branching out of the chemical business, like Allied Chemicals, now Allied Signal. Only in rare cases was the new direction based on real internal expertise in the company, and therefore, the need was more for managerial excellence than for technical excellence. The synergetic effect of several lines of business was often very positive, but sometimes led to excessive strain on the successful products that had to support the newer or weaker products.

10. Demerger.

This newer approach has not yet appeared in Business Schools doctorate theses. It calls for splitting the existing organization into separate entities, without divestiture, so that each part can have a different culture more fitting to its lines of products. Each part can also have different marketing, investment and R&D policies. The most prominent case is the split of ICI, but several other smaller companies have made steps in the same direction (173). For example the spin-offs to shareholders at Eastman Kodak, Ethyl and Cytec. Roberts suggested (149) that the Ethyl and Cytec transactions, particularly, are efforts to isolate lower businesses that were coloring investors' perceptions of the entire corporation. For example, Ethyl's petrochemical businesses were depressing the value of its lubricants and fuel additives operations. Many other companies are presently studying the possibility of demerger. Manfred Schneider, the chairman of Bayer has declared (149) that the company analyzed the possibility of splitting Bayer and decided against it because it would lose some of the synergies, but the company will reexamine the situation every 3 years or so.

11. Reengineering

A fashionable trend described in detail in a recent publication (147) is more of a paradigm than a concise system of procedures. It is defined by Hammer and Champy in their book Reengineering of a Corporation (148) as follows: "The fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance - such as cost, quality, service and speed."

The basic approach is that the performance should not be only improved but that it should be redesigned. Earlier versions of this approach such as zero basis planning did not attain the catch word broad appeal, as reengineering, probably because fewer people recognized the need earlier.

New developments in computer techniques were of crucial importance for success of the Reengineering approach. The computers are not trying to cut the redundant corners, and computer programs cannot pick and concentrate on the most important priorities, as human analysts do, but can be used to check a wider range of options. For instance, Union Carbide claims that it started its restructuring by changing its entire mindset. The concept is new, and fashionable. Its users will have the opportunity to find out if it is a new name for old tricks, or a new remedy for an ailing industry.

3. The global chemical industry.

3.1 Comparison of the chemical industry in different countries.

A compact comparison of the chemical industry in 13 countries is tabulated in Table 9. East-European countries were not included since the fluctuation of the production rates in recent years were influenced more by political changes (sometimes unpredictable) than by the economy.

The parameters of the comparisons are:

1. The chemical sales for 1991-2.
2. The production growth rate for 1991-2.
3. The mean production growth rate for 1987-92,
4. The chemical added value for 1991.
5. The ratio of the chemical added value to the chemical sales for 1991.

TABLE 9
The parameters of the chemical industry in different countries (132,133,138)

Country	Sales 1991 $MMM	Sales 1992 $MMM	Prod growth 92/91 %	Prod growth 91/90 %	Mean Prod growth 87/92 %	Added Value 1991 $MMM	Ratio of Added Value to sales 1991 %
USA	289.0	297.0	2	-2	1.3	156	54
UK	51.1	52.8	2	3	2.5	22	43
Germany	106.3	105.6	1	2	2.5	56	53
Japan	180.0		0	2	2.5	87	48
Italy	51.3	52.0	0	-1	0.8	17	33
France	68.5	68.4	6	2	4	22	33
China	39.6	43.6	10	-1	4.8	14	35
Switzerland	15.8	17.0	4	1	3.0	9	56
S. Korea	20.0		12	12	14	6	30
Spain	39.4	39.9	2	-1	2.5	9	23
Belgium	29.6	29.6	2	0	2.5	6	21
Netherlands	25.0	24.6	2	0	2.5	7	28
Israel	3.8	4.0	9.5	5.1	4.9	1	26

The outstanding performance of South Korea should be noted. South Korea has maintained a high mean production growth rate for the 1987-92, with a high ratio of chemical added value to chemical shipments.

China has shown a good performance in 1992 and 1993. It is too early to estimate if this trend is a stable one, as some signs of inflation appear there.

Israel, with almost 5% of mean annual growth rate shows a better performance than most Western countries, but is lagging behind Korea (and other East-Asian countries, not shown), and was overtaken by China in 1992.

3.3 USA

3.3.1 Growth trends

The US chemical industry is aware that the recent and current slumps are complex. The recipes for change that have been tried have not been effective in most cases. Since the publication of "Made in America" (144) the chemical industry has been urged to divest commodities and to look for specialties with added value. However, non-critical favoring of specialties has not turned out to be a panacea (156), and downsizing turned out many times to be outright detrimental (146).

FIGURE 2: US commodities and chemical production indices, 1971-1992 (138)

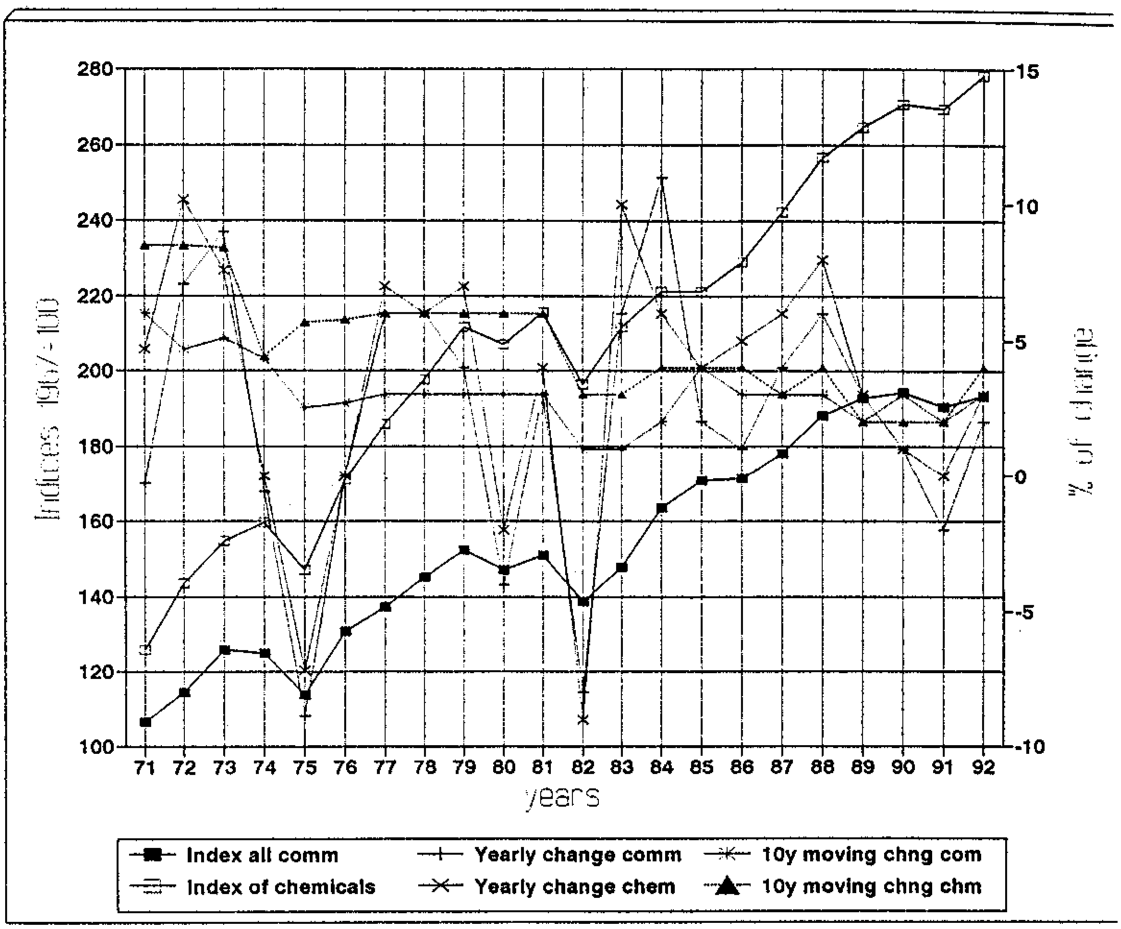


Figure 2 shows the US production indices over the past 22 years, the yearly changes and a 10-year averaged running change, for all commodities and for chemical products. The last shows three drops: in 1973 and in 1982 and a smaller drop in 1989. The 10 year index for chemical products has lost its advantage over the 10 year commodities index. The 10-year running index grew by 9-9.5% for many years till 1973, about 2.5 to 3.5% higher than the all-commodities rise. After the 1973 crisis there was a drop of about 3% in both indices. After the end of the high inflation period in the US, after 1982, both indices converged to rises of abound 2 to 3% per year.

FIGURE 3: US chemical segments production indices, 1971 - 1992 (138)

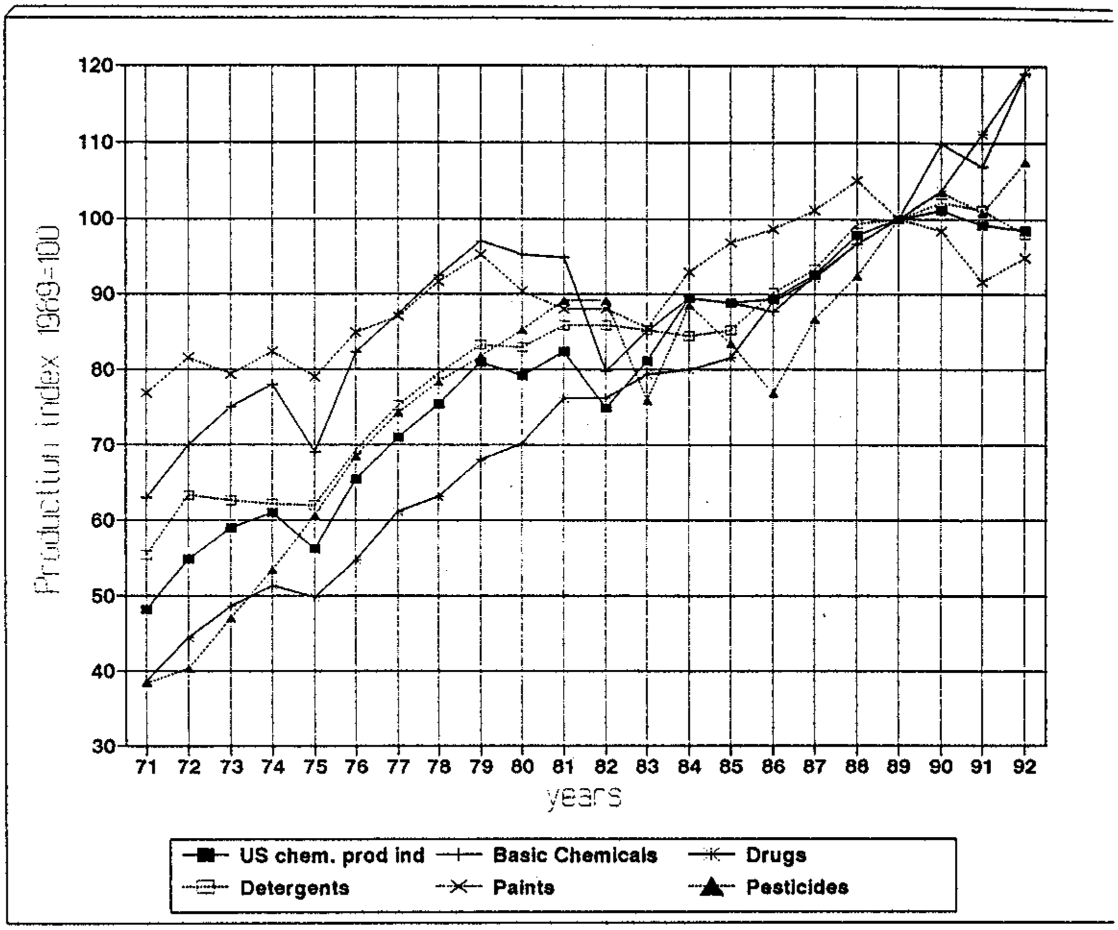


Figure 3 shows the Chemical production index (1989=100) expanded by segments, over the past 22 years. At different years, different segments of the industry rose at different rates. However, over the whole period the greatest rise was for drugs and pesticides.

FIGURE 4: US commodities and chemicals price indices, 1971 - 1992 (138)

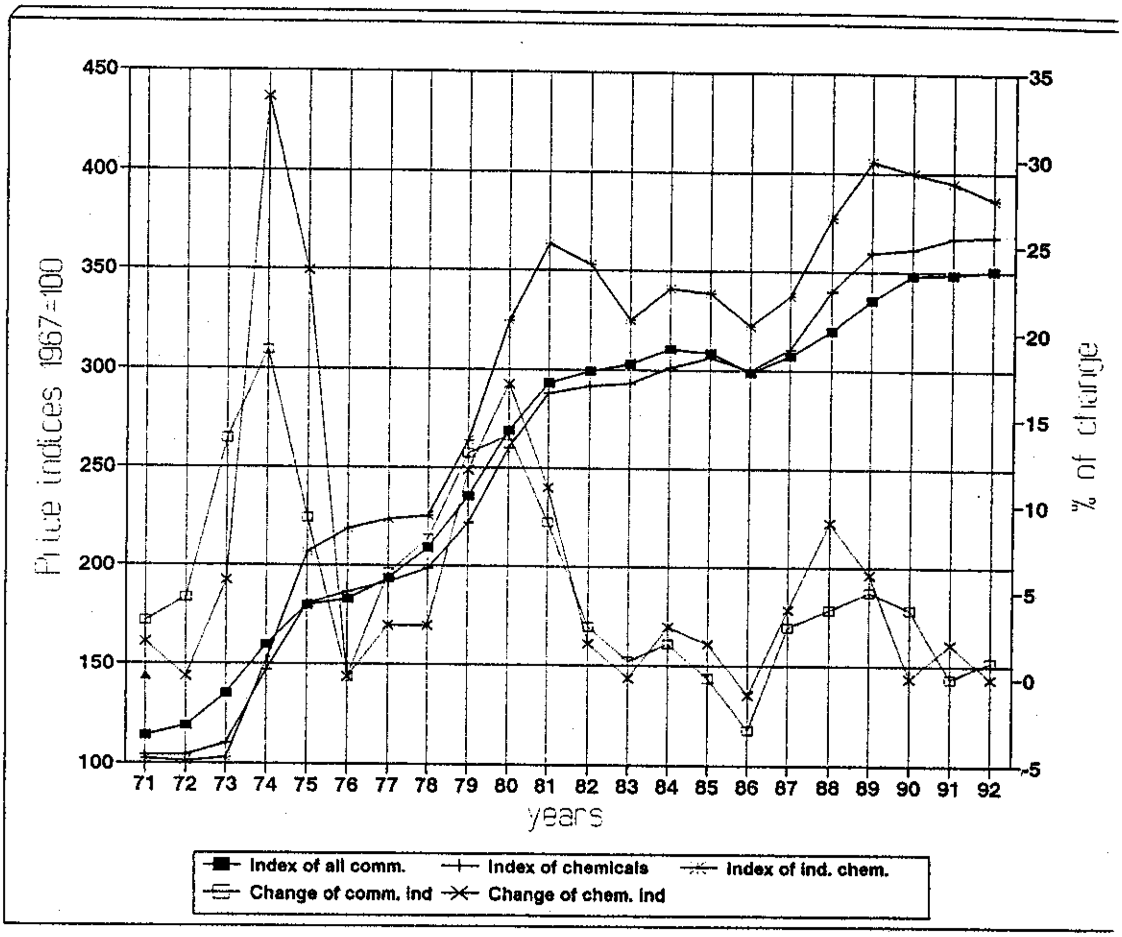


Figure 4 shows the price behavior of the all US commodities, chemicals and industrial chemicals. The chemicals price index reflects the sharp rise after the 1973 oil crisis, and the 1976 - 1982 inflation, and the "good" years of 1988 to 1991. The chemicals price index was in most years higher than the commodities price index by a small margin. The price index of industrial chemicals, rose faster, with the surge of demand at the end of the high inflation period.

3.3.2 The large companies

A general overview of the recent performance of the larger US companies is shown in Table 10:

TABLE 10
US Chemical employment and productivity (169)

Company	Sales $MM 1991	Sales $MM 1993	Employees 1991	Employees 1993	Sales/ Employe $M 1991	Sales/ Employe $M 1993	EBIT margin % 1991	EBIT margin % 1993
DuPont	38,965	37,325	74,611	66,627	522.2	560.1	8.2	8.7
W.R. Grace	2,544	3,008	32,433	25,411	78.4	118.4	15.9	12.7
Dow Chemical	18,807	18,525	24,193	21,300	777.4	869.7	8.9	9.5
American Cyanamid	4,986	5,817	17,145	18,298	290.8	317.9	16.0	15.5
Eastman Chemical	3,614	4,125	16,915	17,926	213.7	230.1	14.8	12.8
Hercules	2,929	2,826	17,324	15,419	169.1	183.3	8.7	10.8
Monsanto	8,864	7,955	12,200	11,100	726.6	716.7	11.5	10.0
Union Carbide	4,877	4,725	13,184	11,025	369.9	428.6	5.2	7.1
Air Products	2,931	3,300	10,292	10,184	284.8	324.0	14.0	14.3
Quantum Chemical	2,532	2,443	8,930	8,730	283.6	179.8	3.5	4.5
Rohm and Haas	2,763	3,360	8,400	8,000	328.9	420.0	9.0	11.3
Ethyl	1,535	1,795	5,228	4,196	293.6	427.8	15.8	15.2
Dexter	938	892	3,350	3,424	279.9	260.4	10.5	13.0
Lubrizol	1,476	1,536	2,907	2,937	507.7	523.0	10.8	10.3
Lyndell	5,729	4,288	2,270	2,407	2523.8	1781.5	7.0	2.5
Ferro	1,057	1,077	2,276	2,314	464.4	465.4	10.2	12.5

The 1993 figures are estimates, and EBIT margins are the earnings before interest and taxes as percent of sales.

The sales figures are the total for the company, but the employment figures are for US employment only. Therefore, the efficiency figures can be misleading. However, since most of the personnel reduction in 1991-1992 was in US personnel, the increase in sales/employee for companies with decrease in sales can be attributed to the reduction in personnel.

The sales of five of the largest chemical companies in the US (DuPont, Dow, Monsanto, Union Carbide and Celanese), on the basis of their deflated turnover over the period of 1971 to 1992 are shown in Figure 5. In deflated dollars the performances of Union Carbide and Monsanto and of DuPont after 1978 are unimpressive. Celanese was bought by Hoechst in 1986 and combined with the other Hoechst holdings in the US, and hence the rise in its performance in 1986 and 1987. The only company of these five to show an improved performance over most of that period is Dow.

The net profits (as % of the sales) for the first 4 companies of the above plus Great Lakes and Bristol Myers are shown in Figure 6. The four larger companies show declining profit margins from 1973 to 1985, a rise from 1986 to 1989 and a decline afterwards. Here again the top performer of the 4 was generally Dow. The two smaller companies showed much higher profit margins than the large companies, but with large fluctuations for the case of Great Lakes.

FIGURE 5: Sales of five of the largest US chemical companies for 1971-1992 (in deflated 1967 $)

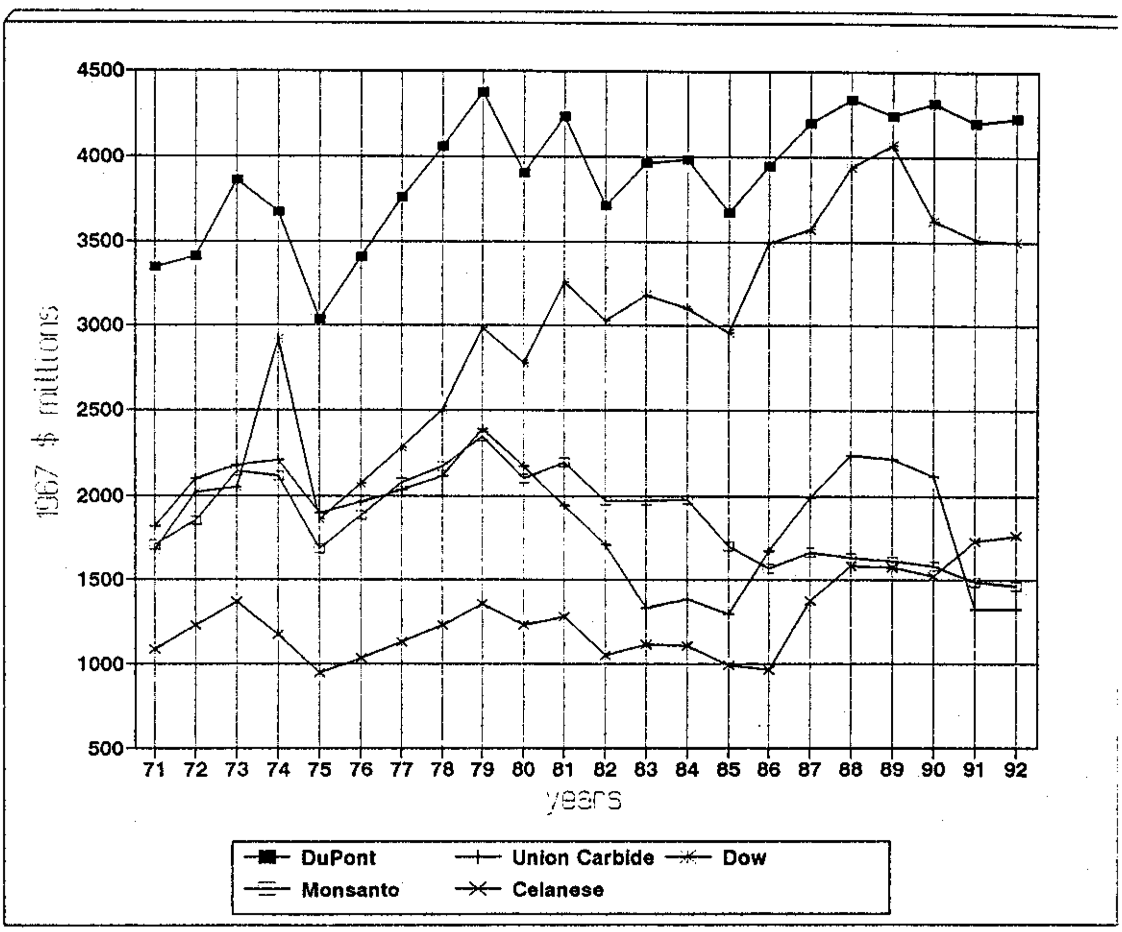
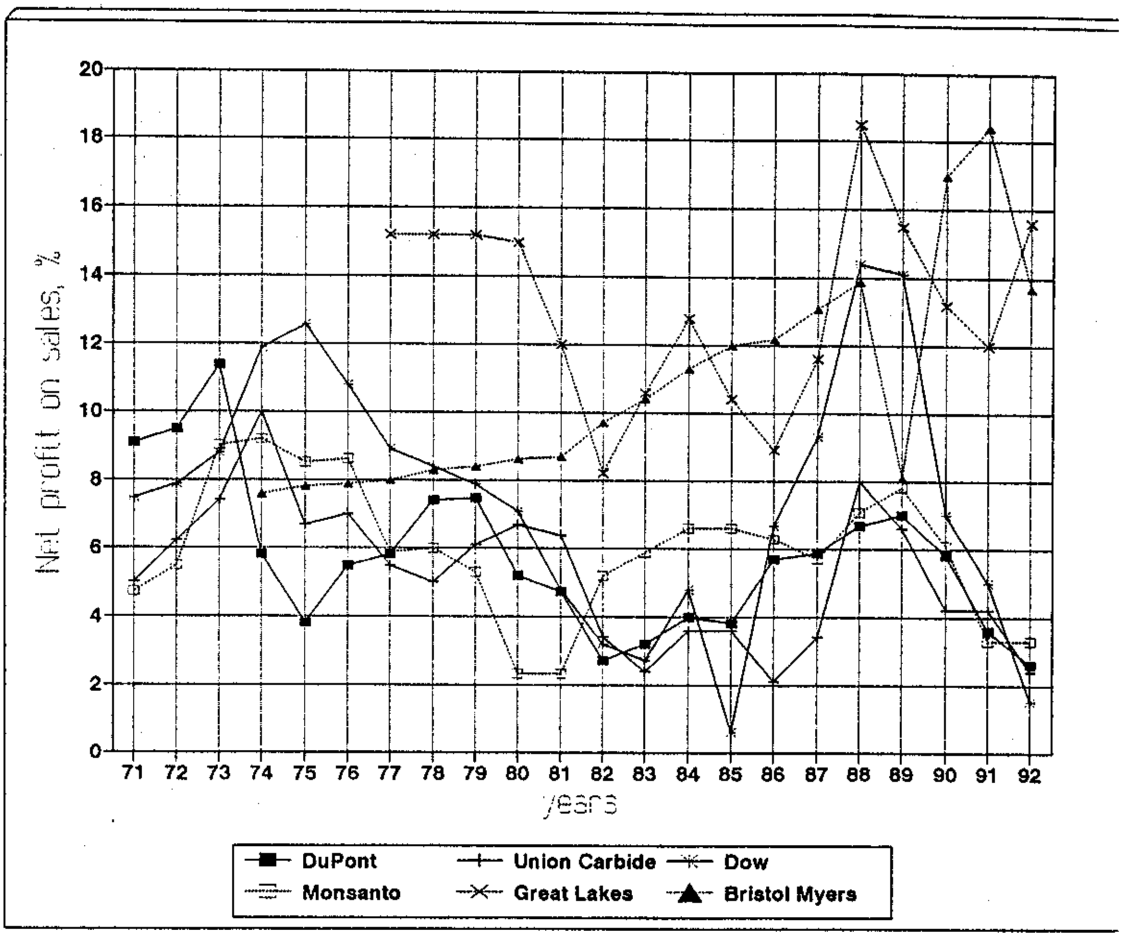


FIGURE 6: Net profits for 6 US chemical companies for 1971-1992 (as percent of sales)



The performance of Union Carbide, Dow and Great Lakes, will be analyzed in greater detail in the following sections.

3.3.2.1 Union Carbide

The Union Carbide corporation has dropped from the number 2 producer in the early sixties to number 5 today. During that period Dow rose from number 4 to number 2 and is not too far behind the leader, DuPont, in chemical sales.

In its early history at the turn of the century Union Carbide main products were calcium carbide and acetylene. From this starting point it developed 5 main business centers (145):

1. Chemicals, Mainly ethylene derivatives: ethylene oxide, styrene, and vinyl chloride)
2. Plastics: polyethylene, polypropylene, and phenolics.
3. Gases and related products: oxygen etc., molecular sieves, cryogenic equipment.
4. Metals and special carbons.
5. Consumer and related products: antifreeze, batteries, lamps.

Later, the pesticides started to be prominent products (up to the infamous Bhopal disaster). However, there are no clear integration links between the different business areas.

The three basic points of the company strategy (similar to many other companies) were:

1. Strengthening of existing businesses.
2. Withdrawing from areas with little potential.
3. Shifting the product mix towards "performance materials".

This policy gave excellent results till the early seventies.Then two processes began:

1. The oil companies entered the petrochemical field, endangering the polyethylene business.

2. Many chemical companies started to integrate backwards, into the domain of oil companies, in order to fight the effects of the oil crisis, often using highly leveraged financing (136).

Union Carbide dominated the polyethylene business, being a commercial and a technological leader, it had to maintain its standing. However, it was against its policy to enter the oil business or to undertake heavy debts. The company financed its attempts to keep its market share by selling its other polymer businesses. In hindsight it was a doubtful move. Table 11 originating from McKinsey & Co., illustrates that the company lost capacity share in all its polymer businesses.

Two other events: retirement from European production, and the Bhopal disaster brought Union Carbide to its present situation, the last among the big 5 of the American Chemical industry.

Two other events: retirement from European production, and the Bhopal disaster brought Union Carbide to its present situation, the last among the big 5 of the American Chemical industry.

TABLE 11
Union Carbide Capacity Share in Ethylene and Derivatives, 1965-1980 (in %) (136)

YEAR	1965	1970	1973	1974	1975	1980
Ethylene	30.5	24.3	17.4	18.2	16.4	10.7
LDPE	31.1	23.2	18.6	20.2	10.1	16.4
HDPE	13.7	12.6	5.4	5.4	10.5	6.6
Polystyrene	10.7	5.8	6.8	7.6		
PVC	10.3	9.4	6.3	6.1	6.1	2.3

3.3.2.2 Dow

Dow is the only one among the large US chemical companies to show a significant growth rate (in constant dollars) over the past two decades, as was shown in Figure 5. The strategy of Dow appears to be vertical integration, growing into consumer specialties with high profit margins while not abandoning commodities and industrial specialties and trying to obtain a 1:1:1 ratio among these three classes (150). This strategy is consistent with the importance of the higher added value, without giving up the advantages of scale of a very large company.

A possible explanation is (150) that Dow is on track in its strategy for product mix. Several years ago Dow management set the goal to boost specialties to 50% of sales. That strategy has been revamped to differentiate between industrial and consumer specialties. Dow's president, Stavropoulos, says that the company is driving for sales divided equally among basics, consumer specialties and industrial specialties. Dow is not far from attaining that mix: basic chemicals and plastics account for 41% of sales; industrial specialties, 26%; and consumer specialties, 32%.

The consumer specialties sector is where most of the profit is derived. Although Dow is the sixth largest chemical company in the world, it aims to take on many of the characteristics and the flexibility of a small company. It is praised for its superior vertical integration. Dow has not neglected modern technology, and has developed the Insite metallocene based catalyst technology, that is changing the way polyolefin are produced. Dow has built new capacity for superabsorbent polymer and new separation systems based on membranes.

Dow's consumer specialties segment is composed of three businesses: agricultural products, pharmaceuticals and consumer products. The first two are self-explanatory. The consumer products include: bathroom cleaner, Fantastik cleaner, Wrap plastic films, laundry detergents, plastic bags, apple pectin, hair care products. Not everything goes well in this segment: the pharmaceuticals company Marion Merrel Dow has profit problems and spoils the performance of the mother company.

3.4 Germany

Germany is the cradle of the modern chemical industry, and with annual sales of \$MMM 100 is still the largest one in Europe, and number 3 worldwide. Its three leading chemical companies, BASF, Hoechst, and Bayer are numbers 1,2 and 4 in the global top 50 chemical companies, after the drop of ICI from the No 1 to the No 3 position, after its split.

The German chemical industry suffers from the same problems, as the other chemical industries in Western countries: low, occasionally negative growth, low profits, and deteriorating trade balance. It has additional problems arising from the unification with East Germany. The chemical output of East Germany is only about 3% of the combined output, but its productivity is low, and the renewal investment is very high (155).

Additional problems of the German chemical industry are: Very high environmental spending- 1.6% of the GNP, and high cost of electricity, \$0.09/ kWh (155). Still, the general feeling in the industry is that the situation is under control, and that no special measures have to be undertaken. This may be the result of the unusually high added value of the industry (56% of the total shipments value).

The performance of the three largest German chemical companies is shown in Table 12:

TABLE 12
The performance of the largest German chemical companies(138,158)

Company	Sales 1991 \$MMM	Sales 1992 \$MMM	Net profit 1992 \$MMM	Capital spending % of sales	R&D % of sales
Hoechst	30.247	29.403	2.6	8.24	6.3
BASF	29.888	28.540	1.4	9.3	4.6
Bayer	27.180	26.407	3.7	6.9	7.5

The growth rate is negative. The profits are low, but positive, probably due to the high weight of pharmaceuticals among the products. Spending on R&D is higher than for the US companies.

The next three largest companies, Henkel (No. 22 in world ranking), Degussa (No 47) and Huels have only a third or less of the turnover of the first three. Their performance is similar.

Dow was one of the most cited cases of restructuring. Bower (135) wrote: "Until very recently, Dow's strategy might be crudely summarized as follows: to be the world's largest and most profitable producer of commodity chemicals and plastics based on low-cost, using leadership and aggressive marketing in the businesses where it competed. Low costs, in turn, were achieved by vertical integration, technical excellence, near or maximum scale, and leveraged financing. When oil prices skyrocketed, Dow sought integration further back to reduce cost. ...It was ready and willing to use debt to fund a program of backward integration into oil and gas. But the high interest rates and declining real energy prices of the eighties that precipitously altered the attractiveness of Dow's portfolio. It had to scramble to generate funds to eliminate debts, liquidating some of the investments. Resources freed by these measures were used to reduce debt and increase the investment in agricultural chemicals, pharmaceuticals and specialties". The managers of Dow stated: "We were back integrated. But today, you only make your profit at the forward end. You can't afford to back integrate".

The profit situation of the company is curious (Figure 6). During the short improvement of the chemical industry, around the year 1988, the net earnings of Dow improved dramatically, and reached almost 15%. However, in 1992 they dropped to around 2%, like the other leaders. (This may be due to a one time change in accounting practice).

3.3.2.3 Great Lakes

This company can serve as an example of a non-pharmaceutical company, that shows an unusually high profit margin (Figure 6).

From a study of the performance of this company (152.153.154), the following picture is derived: The sales growth averaged 24.3% per year since 1989 and the net income has also increased by 24.3%. The chairman, E. Kampen, believes that the company can continue to grow at this rate, because of its entrepreneurial culture and its proficiency at managing changes. At any given point of time, 50% of its businesses are undergoing change.

The company has three basic product lines: bromine, furfural and gasoline additives, and each line is integrated from basic raw material to final products, up to consumer goods. Recently great Lakes has acquired Word Blenkinsop from Shell, thus becoming basic also in phosgene products. In general, all its growth has been through acquisitions, made possible by its outstanding cash flow, which distinguishes Great Lakes from other specialties companies.

Great Lakes spending on R&D is rather low. It was 4.5% on sales in 1988, but dropped to 2.8% in 1991. The healthy cash flow alone cannot explain the high profit rate. Even after deducting the equivalent of the interest rate - the profit stays higher than average.

3.5 Great Britain

ICI is the only one chemical company in UK in the over $MMM 10 class. Despite several attempts of restructuring in recent years ICI found itself in very difficult situation. Its total sales fell from $MM 22,802 in 1990 to $MM 21,309 in 1992. In 1992, for the first time in recent years, it had a net loss of $MM 500. The reaction of the board was swift and unexpected. The board decided on an immediate demerger, in the form of a split between the heavy basic chemicals and the biotechnology, health care and agricultural chemicals businesses. The last businesses representing more than 1/3 of the turnover, were given the name of Zeneca. Each part will be free to develop its own culture and strategy. ICI intended to invest more heavily in its cash cow part, and after the split they could more easily attract investors.

Denis Henderson, the chairman of ICI and Zeneca, and the initiator of the split said (23): "...size and tradition alone are not enough to ensure survival. ... Cross-subsidization has often gone on too long and too expensively. The Demerger has to some extent reduced the comfort factor and I believe the impact of that will ultimately prove beneficial." This change comes at the expense of vertical integration, and it is still to be seen how what the reaction on the added value will be, and what will be the influence of the split on the R&D expenses (about 6% before the split).

Another trend said to be invented by Henderson (173) is the "swap shop": The nylon for acrylics swap with DuPont that was conditionally approved in September 1992 and that took place a few month later, and the polypropylene for acrylics swap with BASF that was announced in January 1993. Since acrylics are among the most promising polymers at present (34), these swaps may be advantageous to ICI.

Other British companies like BP, Shell and Octel (A subsidiary of Great Lakes) are trying to follow this lead. On the whole, British industry has, as in the past, showed original thinking in dealing with its situation. It is too early to judge the outcome.

3.6 France

An accepted view among the Western economists, is that the private ownership makes industrial companies more efficient and competitive. France, more than other Western countries, took this axiom with some reservations. David Hunter suggests (161) that nationalization in 1981 saved Rhone-Poulenc from bankruptcy or break-up. State control has prevented RP from raising equity by issuing shares, forcing it to resort to inventive but expensive instruments to finance its growth. But state ownership has permitted it to operate with much higher debt than a private company. This had made possible its aggressive acquisitions strategy, spending $MMM 6.8 between 1986 and 1991 to reshape its portfolio toward biosciences and specialties, and build a US presence. All this was going to change with the sale of the state's remaining 43% holding in 1993.

France has no ideological policy of nationalization of private industry, but such actions are part of the arsenal of means of governmental influence. This government influence is more pronounced in the R&D policy, where the government sometimes deals directly with technological development in areas which other governments leave to the industry. In many areas, including some belonging or bordering on the chemical domain, the government support of R&D gave a significant boost to the French industry.

In the final score, France has the fastest growing chemical industry in Europe, with a record production index (relative to 1985) of 130.

Table 13 presents performance figures for the two largest chemical companies in France with a joint turnover of about 1/3 of the total national turnover.

TABLE 13
Performance of the two largest French chemical companies (138)

Company	Sales 1991 $MMM	Sales 1992 $MMM	Net profit 1992 %	Capital spending % of sales	R&D % of sales
Rhone-Poulenc	15.844	15.445	2.7	6.9	7.1
Air-Liquide	6.015	5.537	7.6	11.8	1.6

The current growth rate is negative. The profitability and capital spending of Air Liquide are high. The R&D spending of Rhone-Poulenc is high.

3.7 The Netherlands

It may be significant that the Netherlands, with its large chemical industry (around $MMM 25, almost completely export oriented) with 3 companies in the top 25 of the world list (Chemicals sales of Shell $MMM 10.3 (including UK holdings), of AKZO - $MMM 7.7 and of DSM $MMM 5 in 1992) is found at the bottom of the added value classification (Table 3).

J. Schoenmakers (159), suggested that the process of restructuring and concentrating on strong product-market combinations was delayed by the economic boom of the 1980s, which temporarily made the process less urgent. At that time enough money could be made even with sub-optimal mix. The Dutch chemical industry has not changed much during the past 20 years. Despite the fact everybody said a move toward high added value was of vital importance, the industry is still 60% commodity chemicals production, as it was in the 1970s. As a result, the Dutch chemical sector is still one-sided compared with the diversity of products in Germany. Ammonia, salt, and basic plastics account for 80% of the total chemical production in the Netherlands.

3.8 Switzerland

Three Swiss companies, Ciba, Sandoz and Roche, with a joint turnover of over \$MMM 25 per year, present one of the most powerful concentrations of chemical industries in Europe. Their leading position in pharmaceuticals and dyes is well known, but their involvement in basic organic and inorganic chemicals is also prominent. Switzerland presents probably the best integrated chemical industry in Europe, with most sales at the consumer end of the line. Therefore, it appears, in sharp contrast to the Netherlands, at the top of the classification by the added value (Table 3). As a result, the profit margins of the Swiss companies are unusually high for the European environment: 10.4% for Sandoz, 6.8% for Ciba and 14.8% for Roche. More significantly, for all these three companies, the profits have risen consistently during the past 3 years (138).

3.9. Japan

The legend that the Japanese chemical industry (second largest in the world at \$MMM 180) will not be touched by the recession was incorrect. In 1992 a slow-down started to spread, commencing from the petrochemical industry, exactly as described by Bower (135) a decade earlier. There are no signs yet of recovery, despite the usual heavy involvement by the government, which at this moment is not very effective. It will be interesting to observe, if the proximity and close ties binding Japan with the countries of the Pacific Rim will have a smoothing effect on this recession.

Other factors which may influence the recovery: The Japanese chemical industry is very decentralized, the 12 largest chemical companies do not account even for 1/3 of the total chemical sales, (very unlike the other industrialized countries). The largest company, Asahi Chemical (No 13 in the worlds top 50 list), has sales under \$MMM 8. This may add flexibility to the fight with recession. The government, on its part, has curbed administratively chemical imports, thus attempting to protect the local production (152).

For illustration of the present situation in Japan, Table 14 shows the net sales and profits of 6 leading chemical companies:

For 4 companies the growth rate was negative (It used to be at least 4% per year). Toray and Takeda produce mainly pharmaceuticals, hence the higher profits. For the other companies the 1992 profits are less than half of the profit in recent years.

TABLE 14
Performance of some Japanese chemical companies (138)

Company	Net Sales 1991 $MMM	Net Sales 1992 $MMM	Net profit 1992 % of sales
Asahi Chemical	7694	7849	1.7
Mitsubishi Kasei	5740	5602	0.7
Sumitomo Chemical	5554	4926	0.9
Sekisui Chemical	5130	5324	1.5
Toray Industries	4729	4578	4.1
Showa Denko	4552	4015	1.3
Takeda Chemical	4427	4458	5.6

3.10 China

In its efforts to change from a communist economy to a more competitive form, China took the diametrically opposite direction of Russia, i.e. by relaxing the centralist rule over the economy before changing the political regime. So far, this formula seems to work better than the Russian formula. Its essence: to delegate the immediate tasks to private, competitive hands, while keeping the long term planning with the central government. The comparison with the former Soviet Union is not completely fair: China has a much larger more population, but since the economy is much smaller, it is easier to manage. The growth rate of the Chinese chemical industry in 1992 was twice its average rate in the 5 earlier years (Table 9).

A more detailed picture of the recent growth of the Chinese chemical production is shown in Table 15:

Although the quantities shown in Table 15 are large, the per capita use is still very small.

The ten largest chemical companies in China in 1992 are listed in Table 16:

All companies in this list (with the exception of Jilin) are named as petrochemical companies. The majority of companies with typically chemical names can be found much lower on the list, with annual sales reaching $MM 300 or less. The total output of the Chinese chemical industry was reported for the year 1992 to be $MMM 43.6, 10% higher than in the previous year.

TABLE 15
The growth of Chinese chemical production
(in 1000 metric tons)

Product	Thousand tons				% change
	1989	1990	1991	1992	91/92
Ammonia	20675	21251	21973	22965	5
Fertilizers	18547	18790	19783	20990	6
Sulfuric acid	11408	11967	13333	13960	5
Sodium hydroxide	3211	3388	3533	3778	7
Sodium carbonate	2983	3799	3935	4506	14
Plastics	1973	2249	2640	3142	19
Synthetic fibers	1466	1655	1909	2083	9
Detergents	1431	1516	1461	1616	11
Ethylene	1405	1572	1746	1982	14
Pesticides	224	228	255	284	11
Drugs	196	172	195	219	12
Synthetic rubber	289	315	335	366	9

TABLE 16
The ten largest chemical companies in China in 1992
(An exchange rate of $1 = 5 yuan was assumed)

	$MMM
Shanghai	1.7
Beijing Yanshan	1.5
Jilu	1.3
Jilin Chemical	1.2
Daqing	1.2
Wushun	1.2
Maoming	1.1
Jinling	1.0
Shanghai Gaoquiao	1.0
Yangzhi	0.9

he growth rate of the Chinese chemical industry appears to be limited only by the buying power of the population of the country (and to some extent on the success of exports. Currently the balance of the chemical trade is a negative $MMM 5). The possibility of its reversal is not clear. The Chinese Minister of chemicals, Mrs. Gu Xiulian complained that the first half of 1993 showed only 6.7% growth (over the matching period in 1992) because of the cuts in government subsidies to agricultural chemicals (162).

Shahid Burki, director of the World Bank's China Department predicted an 8.5% annual increase in China's GDP for 1992-2000, taking the GNP from $MMM 370 in 1991 to $MMM 730 in 2000. The income per capita will rise from $370 in 1991 to $560 in 2000 in real terms. Under such a scenario, China will still be a poor country. Estimates saying that the income per capita will reach $4000 are dismissed by the World Bank. On this basis the 10% growth target set by the government for the chemical industry is possible, following the 1992 rate of growth.

In a few of China's regions, that are autonomous to some extent, for example: Guandong, Fujian, Jiangsu and Shandong, called the "Inner Dragons" the development is even faster. The chemical industry there is expected to grow at a spectacular rate.

The two economic problems of China are: To build the markets for future expansion, and to obtain funds for investments. This second problem is not so acute, since many among the "Chinese Diaspora" developed "China fever". According to the Ministry for Foreign Trade and Economic Relations ("Moftec"), of the $MMM 37 in foreign investment in 1979 - 1992, $MMM 21 came from Hong Kong and Macao and further $MMM 2 came from Taiwan. This investment stream is widening each year. Chemical companies from all over the world are investing in China. Hoechst has investment projects in China for over $MM 400 in 5 years.

The ratio of added value to the chemical output value is 35% (Table 3). This may be a consequence of good integration of the industry, starting from basic petrochemicals and, perhaps, lack of foreign currency for imported raw materials.

The per-capita added value in China is under $100, (Compared to over $5000 in the USA, and about $1800 p.a. in Israel). Since even at that national efficiency the Chinese chemical industry is among the first ten in the world - it is clear that it will have an impact on the world chemicals market.

3.11 South Korea

South Korea was chosen here as the main representative of the "Little Dragons". The original "little Dragons", one of the most interesting phenomena of contemporary economics, included South Korea, Taiwan, Hong Kong and Singapore. In the last decade their economy, including the chemical industry, has shown a continuous boom. It started, by high productivity, caused partially by low wages. This attracted foreign industry, which erected local daughter production companies. As a result, foreign technology was imported, foreign loans helped to erect industrial infrastructure and local specialists acquired high technical skills.

With the rising local income, the market developed quickly and induced further development. This reasoning, while plausible, does not explain why such development did not take place at many other countries. Possibly, the Japanese influence was a factor, not always in Japan's favor. J. Greenwald is quoted in Time (163): "According to Sanwa Research Institute, Japan stands to lose 1.3 million jobs by the end of the decade if companies continue to accelerate the rate at which they build foreign factories."

Currently, new "Little Dragons" are appearing: Malaysia, Indonesia, and Thailand. Even Vietnam is mentioned as a new economical miracle of the Far East.

The development rate of the chemical industry in South Korea resembles those of West Europe in the sixties, and is better than the overall (and impressive) figures for all the South Korean industry as can be seen in Table 17:

TABLE 17
The Korean industrial trends Production index
(1985=100) (138)

	1989	1990	1991	1992	% change 92/91
All Manufacturing	171.3	186.5	202.6	212.3	5
Chemicals & allied products	154.8	172.9	194.2	218.2	12
Industrial chemicals	156.6	188.6	222.9	271.1	22

The highest growth rate, over 70%, was in ethylene, propylene, benzene and butadiene.

4. The Israeli chemical industry

4.1. Scope of the information

Most of the sources of information about the Israeli chemical industry were created either in order to interest buyers and investors (164,165,166) or as part of general statistical information, covering all segments of the industry (167,168,169), and are occasionally inaccurate.

The behavior of the chemical industry in Israel changed with the passage of time. The most pronounced characteristic being the rate of growth, but other changes include the attitude towards investments, R&D, and long-term development.

There is no available organized information describing the development of the Israeli chemical industry over the years and presenting the changes and unusual occurrences as they took place. Such information is required in order to observe and analyze trends, and this information has to be collected from various sources inside and outside the industry.

We have used the available information about the Israeli industry and the chemical segment of the Israeli industry. We have collected information about individual companies, whenever available, and collected data about turnover (over 5 years, if possible), exports, the line of products, from which the market distribution could be estimated. We could not get adequate data about investments, and information about profits was available only for public companies. No effort was made to quantify R&D efforts. The integrated results reported by the companies were compared with the overall data for the chemical industry published by official agencies.

In addition to the collection and analysis of data, two original contributions are presented:

1. The comparison of the added value of the Israeli chemical industry with other countries which were presented in Tables 2 and 3.

2. The local and export markets distribution of the products of the Israeli chemical industry presented in Tables 28 and 29.

In the past few years and especially in 1992, the growth rate of the industry went up. The trend appears to be real, but somewhat exaggerated due to the inclusion of petroleum distillation products in the statistics of chemical products.

4.2 Historical Background.

The chemical industry in Israel is relatively young. A few tiny consumer oriented production facilities were built in the twenties, and a small potash plant that was later destroyed during the war of independence was built at the Dead Sea in the thirties. However, the first facility that can be called a chemical plant was the fertilizers plant at Haifa that was built after the Second World War. (The Haifa refineries were built during the war, but at that time included almost exclusively distillation units). Comparably, the European chemical industry, is at least 3 times as old.

The Israeli chemical industry started in 4 separate centers, which still exist as more or less separate entities:

1. The Oil Refineries, erected by the British to help in the war effort, and later formed the basis for the petrochemical industry. This company has also initiated the Haifa Chemicals company, which was later privatized.

2. Fertilizers and Chemicals, Dead Sea Works and Negev Phosphates, producers of fertilizers.

3. Makhteshim and Agan, the leaders in the synthetic pesticides for 4 decades.

4. Pharmaceuticals which started in several locations, but were dominated by Teva, which acquired most of the early pharmaceutical companies..

The first two groups were started by the government. The third group was part of the Union industries and only the fourth group was developed by the private sector.

Bordering the chemical industry was the development of the food processing industry (mainly citrus and oil), and consumer oriented production plants for paints, lacquers, soap, etc.

The output of the 4 main centers has grown steadily and their orientation has changed from supplying the local markets only, to exports.

Mergers and other conglomerations (such as the Teva - Abic, Makhteshim Agan, Negev Phosphates - Rotem Fertilizers mergers) were usually within the same market orientation and did not lead to the development of multidisciplinary corporations typical of the chemical industry in the world.

The largest chemical corporation, Israel Chemicals, is the closest to a multidisciplinary concern but is still dominated by the mineral raw materials it uses and the agricultural market.

This structure can partly explain why several product lines, important in the world, are missing in the existing organizational grid, and why there is limited vertical integration, and hence low added value to the national economy.

Two other characteristic features of the chemical industry in Israel:

1. It was difficult to buy know-how licenses from foreign companies, partly due to the small internal market, and partly due to the Arab boycott. This was particularly pronounced in the pharmaceutical and pesticides industry, and encouraged the development of production processes for me-too products, and prevented the erection of large plants, which could have offered the economy of scale. It also made the training of the professional personnel difficult.

2. As the industry became export oriented its market development depended on sophisticated local customers for technical feedback. These customers were mainly from the agricultural market. This directed the development of the industry into the cycle prone, low growth, and often depressed agriculture export market.

Another reason for the domination of the agriculture market was the abundance of some raw materials for this market: potash, phosphate, (and also bromine and magnesium salts), and their exploitation was seen as a national priority.

Pesticides were needed for modern agriculture, and their local production was also favored, in order to conserve scarce foreign currency.

The production of chemicals was supported by the government by a system of grants and low interest loans. This support was higher if the project was erected in a location far from the center of the country , which gave an additional boost to locating most the new chemical plants in the Negev.

To some extent the rate of growth of industry was more a function of the financial policy of the current government than of market demand. For instance, the plants built during the onset of the high inflation (in the seventies) received unlinked loans, which were practically grants.

This policy encouraged the fast growth of the chemical industry, and founded a base for future development. There were some inevitable failures, the most prominent of which was the first Arad plant for HCl from magnesium chloride brines using fluidized bed technology.

This policy and a liberal support for research in industry favored a few important technological developments, such as the cold process for potash, the extraction process for high quality phosphoric acid, the Aman process for periclase, the potassium nitrate extraction process and several new processes in the organic pesticides industry. It is not certain that those successful processes would have been implemented if judged only on the basis of an analysis of short-term financial feasibility.

As the chemical industry matured such breakthroughs became increasingly rare, and the growth rate of the industry slowed.

4.3 Salient Statistics.

In most classifications of the chemical industry in the world, the production of fertilizers, is considered as part of the chemical industry. In Israel, for some historical reasons, the production of potash and phosphate rock is listed as "mining and quarrying", under code 10. We took care to include them in our salient statistics. We have also used this separation of classifications in Tables 18 to 21, which give overall data for the chemical production and industrial production in Israel.

TABLE 18
Yearly and average real change of production of the Israeli chemical industry, % (167)

	1988	1989	1990	1991	1992	79-85	85-92	79-92
chemicals	1.0	1.0	4.9	4.2	10.4	2.3	4.8	3.7
mining	-1.6	2.7	5.9	8.6	6.3	2.6	5.4	4.1
total	0.5	1.4	5.1	5.1	9.5	2.4	4.9	3.8

The data in Tables 18 - 21 were not adjusted for distillates. When comparing with foreign data, it was necessary to adjust the numbers by deducting the distillates, which are not considered chemical products in world statistics.

The bias caused by the distillates was greater in the seventies, although unlike last year, this bias acted then in the direction of reducing the real growth rates. In 1975 the distillates represented 63% of the total value of chemicals (without mining), and in 1976 - 62%. The reported real growth rate (adjusted only for inflation) for chemicals in 1975 - 1976 was 4.4%, and in 1976 - 1977 it was 5.1%. (172). After adjusting for the distillates, the adjusted real growth rate was 8% and 9% respectively. In the sixties the adjusted real growth rate of the chemical industry was over 10%.

TABLE 19
The share of chemicals in total Israeli industrial sales, % (167)

	1970	1975	1980	1992
Chemicals	6.6	8.2	9.4	10.8
Mining	2.3	2.6	2.8	1.9
Chemicals and mining	8.9	10.8	12.2	12.7
Industry without diamonds	10	12	14	14

The diamond industry with its low added value distorts the total industry figures. Therefore, the last line shows the share of the chemical industry to the total industry, adjusted for diamonds.

The share of electronics in the total industrial sales rose during those years from 6.4% to 14.5% and has passed the chemical industry. The share of metal products rose from 8.9% to 9.1%.

The total exports of chemicals + mining in current dollars
were : $MM 1454.5 + 300 in 1991 and $MM 1542.2 + 303.6 in 1992 (41).

TABLE 20
Annual and average change of exports of the Israeli chemical industry: (in real terms), % (167)

	1988	1989	1990	1991	1992	79-85	85-92	79-92
Chemicals	4.6	6.6	5.3	2.8	8.9	2.6	8.4	5.9
Mining	-10.7	-0.5	-4.2	-4.1	-4.1	2.6	-3.3	-0.4
Total	1.4	5.1	3.3	1.3	6.3	2.6	5.9	4.6

The sharp change in 1992 caused by a jump in exports of oil distillates after the reform of the oil industry in Israel.

For the first 11 months of 1983, the total exports grew over the similar period last year by 16.4% and without diamonds by 17.5%. The chemicals exports grew by 18%, and mining exports were reduced by 7%. The highest increase was in pharmaceuticals, due to the registration of many new generic medicines.

TABLE 21

The share of chemicals in total Israeli industrial exports, % (167)

	1970	1975	1980	1992
Chemicals	10.2	12.3	15.2	13.5
Mining	7.0	5.6	3.3	2.4
Total chemical industry	17.2	17.9	18.5	15.9
Without diamonds	26.1	28.1	26.3	20.6

The export share of mining has been steadily dropping. Chemicals also suffered from the European market slump in 1992, and with adjustment for distillates their export share would show even a drop in 1992. The best performing industry in recent years was the electronics industry. The share of electronics in total exports rose over those years from 3.2% to 26.1%, and the share of metal products rose from 5.6% to 6.9%.

The gross investment in the chemicals industry was in current NIS 976 millions in 1991 and 1423 millions in 1992, a real growth of 33.1%. (Inflation was around 12%). The investments in mining were 571.9 millions in 1991 and 538.7 millions in 1992, a real decline of 14.2%. The average real growth of investments over the years 1979 -1992 was 10.7% for chemicals, and 1.2% for mining. The share of chemical investments in the total investments in the industry was fairly stable over the period of 1970 - 1992, ranging from 22.9% in 1970, to 26.9% in the 1992. The sales expenses in 1992 amounted to 13% of sales.

The R&D spending of the Israeli chemical industry was low and averaged only 1.5% of sales, about 1/3 of the rates of the Western countries.(167)

4.4 Main Products

The rate of the development of the chemical industry in Israel is shown in Table 22 by an overview of the quantities produced from 1970 to 1992.

TABLE 22
Production of the main Israeli chemical commodities (tons)(168)

Product	Units	1970	1980	1990	1991	1992
Potash	1000 t	869	1343	2124	1958	2086
Phosphate rock	1000 t		2307	2472	2267	2372
Ammonia	t	37745	66702	77582	55056	41072
Amm. sulphate	t	67824	38231	35441	14875	12444
Dicalc. phosph.	t	13516	16466	20820	24738	20515
Sulphuric acid	1000 t	203	209	154	136	138
Chlorine	t	14833	35310	36342	36105	33912
Caustic soda	t	15923	35268	31575	32180	29459
Polyethylene	t	17765	60997	106599	124613	128739
Paints	t	19488	26953	46341	48242	58242

Other important bulk products (1988 figures): Organic solvents - 160000 tons, Polystyrene - 11000 tons, PVC - 80000 tons, MTBE - 12500 toms, Methanol - 40000 tons (171), Pesticides - 100000 tons (170).

4.5 Major Companies

We present here statistical information for 50 chemical companies in Israel. The criterion for picking a company was a turnover in 1991 of over $MM 50. However, we have added a few biotechnology companies with lower turnover. This list of companies includes those engaged in "mining products" and "fuels" (the last represent at least 85% of the output of the Oil Refineries). The list also includes nylon fibers produced by Nilit.

TABLE 23
Turnover of the largest Israeli chemical companies(in current $M) (164)

	1988	1989	1990	1991	1992
Biotech General	2286	7000	1216	1621	2318
Rekah		2000	2000	2300	2300
Rad Chemicals	2200	2100	2310	2500	2500
Biological Ind.	6310	5985	4946	4167	6310
Orgenics	1300	4000	4500	2200	2860
Chemada	4500	5000	5800	5900	6300
Chemagis		2650	6400	6500	7000
Maxima	7040	6987	7000	7000	9000
Deshen Gat	2700	8000	7700	8200	8200
Taro	5900	6201	7656	9142	10981
Makor	7300	7300	6800	9209	7000
Serafon	4000	5175	6348	9277	13000
Vitamed	6000	6429	7910	9649	10000
B.G. Polymers	5000	4797	6104	10254	9000
Pazchem	18000	16300	16000	11475	15000
Rafa			8500	12000	12000
Fisher		10000	12000	12000	12000
Nir Lat	4200	4700	5500	12000	12000
Explosives	7000	5440	8000	14500	4500
Kedem	9600	9325	13000	13000	16000
Pazkar		10037	12642	15464	25000
Dor Chemicals	16000	16000	16000	17500	17500
Trima		19800	17587	17587	21000
Frutarom	12000	13000	14000	15000	18200
Sharon Labs	18000	18000	20500	20000	17000
Luxembourg	10700	17348	15500	18000	18000
Dexxon	9800	12930	15850	19000	25000
Neca	14639	15595	18500	23000	27000
Carmel Chem.	22000	21000	19531	25000	25000
Avco	14500	16000	21000	32000	33000
Zohar Dalia	25881	27600	31360	32200	32000
Interpharm	18000	13772	25200	35196	51600
Sano Bruno's	33026	33881	39021	38298	38000
Periclase	29210	32893	40421	39242	42800
Koffolk	28934	30531	33539	40702	45000
C.T.S.	2800	4946	5000	6000	7200
Abic		49879	56500	58200	68000
Nilit	79471	86612	83418	85012	85000
Fert. & Chem	89500	94319	104085	91971	97900
Gadot	75089	88306	83556	92705	101600
Carmel Olefins	122000	101132	128400	108161	120000
Tambour	90500	92549	94804	108755	120000
Electrochemical	105164	117849	120707	116521	120000
Agan	89027	93579	111202	122996	131500
Makhteshim	136600	157351	172041	172041	178000
Haifa Chemicals	132500	145000	155300	177500	200000
Amfert Phosph.	313000	396935	402000	396700	317000
Bromine Comp.	273299	297800	313501	332000	328000
Teva	211092	268500	295200	320983	396336
Dead Sea Wks	508104	544662	566755	558410	580100
Oil Refineries	375000	615000	797000	827000	933000
Total	2675873	3224516	3499809	3735838	4002005
Israel Chemicals	965806	1010418	1067923	1054685	1065054

The data gathered for the individual companies were taken from several sources, the most important of which is Dun's Guide (38) which uses figures reported by the producers, which may occasionally be biased on the higher side.

Comparing some of our figures with a study performed in 1992 (130) that covered 124 chemical companies, has shown that our list of companies represented 97% of the chemical sales, and 99% of the chemical exports of the Israeli industry.

We have also added a line for Israel Chemicals (controlling Fertilizers and Chemicals, Dead Sea Works, Amfert-Rotem-Phosphates (a recent merger), Periclase, Negev Ceramics, Rami Ceramics, Timna Copper Mines, the bromine companies, and a number of companies abroad and a few non-public companies for which financial data were not available). The figures for Israel Chemicals are sums of the figures presented in the tables for the subsidiary companies included in the tables, and do not represent the total figures for Israel Chemicals.

We have avoided double summation by excluding Israel Chemicals from the totals, since its Israeli daughter companies were listed individually. Abic is now part of The Teva group. The figures for Bromine group appear also in the figures of its mother company, the dead Sea Works, but the duplication was excluded from the totals.

Table 23 presents the turnover of the larger chemical companies in the past 5 years. After deflation to the constant 1988 dollars, the yearly growth rate is calculated and presented in Table 24.

TABLE 24
Adjustment of the totals in Table 23 to 1988 constant $

	1988	1989	1990	1991	1992
Current $M total	2675873	3224516	3499809	3735838	4002005
Deflator	1	1.06	1.06	1.08	1.08
Deflated total	2675873	3041996	3301706	3459109	3705560
Real growth %		14.0	9.0	5.0	7.0
Growth adjusted for fuel		15.0	3.0	7.0	5.0
Reported growth		1.4	5.1	5.1	9.5

Table 25 presents chemical exports of the same companies. The last column indicates if the overall change of the export by the company was positive or negative.

The MA classification of companies is used by the Manufacturers Association of Israel: 1-Mining and quarrying, 2- Petrochemical, 3- Paints, 4- Food additives, 5- Biotechnology, 6- Fuels, 7- Cosmetics, 8- Pesticides, 9- General chemistry, 10- Pharmaceuticals, 11- Intermediates, 12- Fertilizers, 13- Detergents, 14- Medical equipment, 20- Not classified elsewhere.

TABLE 25

The export by Israeli chemical companies (in $M) (164)

Company	1990	1991	1992	Classific.	Gain
Biot General	1034			5	
Rekah				5	
Rad Chemicals	2000	2000		5	
Biological Ind.	3165	1458		5	
Orgenics				5	
Chemada	4250	4250	5500	11	+
Chemagis	5900	6200	6100	11	+
Maxima					
Deshen Gat					
Taro					
Makor	6500	8628	8900	5	+
Serafon					
Vitamed					
B.G. Polymers					
Pazchem	5000	2832	2800	8	-
Rafa					
Fisher	500	2000	2800	10	+
Nir Lat	2000	3000	3000	9	+
Explosives					
Kedem					
Pazkar					
Dor Chemicals		3500	1176	11	-
Trima					
Frutarom					
Sharon Labs	5000	2832	2800	4	-
Luxembourg	11000	14000	14300	8	+
Dexxon					
Neca					
Carmel Chem.		22500	12013	11	-
Avco	4500	9600	10000	13	+
Zohar Dalia	3120	3000	3157	13	
Interpharm		33500	38000	5	+
Sano Bruno's	500	765		8	
Periclase	34298	37279	32405	11	-
Koffolk	21128	22900	22600	11	+
C.T.S.				10	
Abic	15600	17100		10	+
Nilit	82301	84091	85000	20	+
Fert.& Chem.	31166	32592	30955	12	-
Gadot	67736	76573	84100	2	+
Carmel Olefins	52000	39000	36797	2	-
Tambour	6588	8000	7000	3	
Electrochemical	67840	60750	58300	2	-
Agan	92490	118995	115100	8	+
Makhteshim	137700	130100	138600	8	
Haifa Chem	125500	147000	166200	12	+
Rotem-Amfert	81934	95400	169400	12	+
Bromine Comp	213400	318140	329000	11,8	+
Teva	136000	151036	150000	10	+
Dead Sea Wks	496780	496900	563000	10,12	+
Oil Refineries	191000	230000	239000	6	+
Total	1677896	1851715	2009003		
Israel Chemicals	629000	628192	642896		

Several figures were not cross checked and appear to err on the high side. There is a slight inconsistency in the figures concerning Israel Chemicals due to the inclusion of some additional exports from subsidiaries not listed in this table. The negative gains were mainly in polymers.

Table 26 was generated by the same procedure as Table 24:

TABLE 26
Adjustment of the totals in Table 25
to 1988 constant $

	1990	1991	1992
Total exports in $1000	1677896	1851715	2009003
Deflator	1.06	1.08	1.08
Total in Constant $1000	1582921	1714552	1860188
Real growth %		8	8
Reported growth %		1.3	6.3

These figures were not adjusted for distillates.

4.6 Production segments

The development of different segments of the chemical industry in Israel occurred at different rates, and did not follow the pattern of other countries. This can be seen by comparing the production indices by segments for Israel (Figure 7) and for the US (Figure 8).

The growth of the chemical industry, as well as its main segments, was faster in Israel than in the US in particular in the pesticides and the drugs segments.

We have consistent data starting only from 1979, when the very fast development of the pesticides companies has already reached its zenith and the development of pharmaceuticals has just begun. Pharmaceuticals were the leaders from 1979 to 1992. Basic chemicals, have grown fast from 1982 to 1987, with modest growth rates in other periods. The basic
chemicals category is a strange mix of industrial chemicals, fertilizers, monomers, pesticides and intermediates. Changes in capacities of fertilizers on one hand, and of monomers on the other hand influenced the performance of the basic chemicals. The growth index of pesticides changed little during the covered period

FIGURE 7: The production of the Israeli chemical industry by segments.

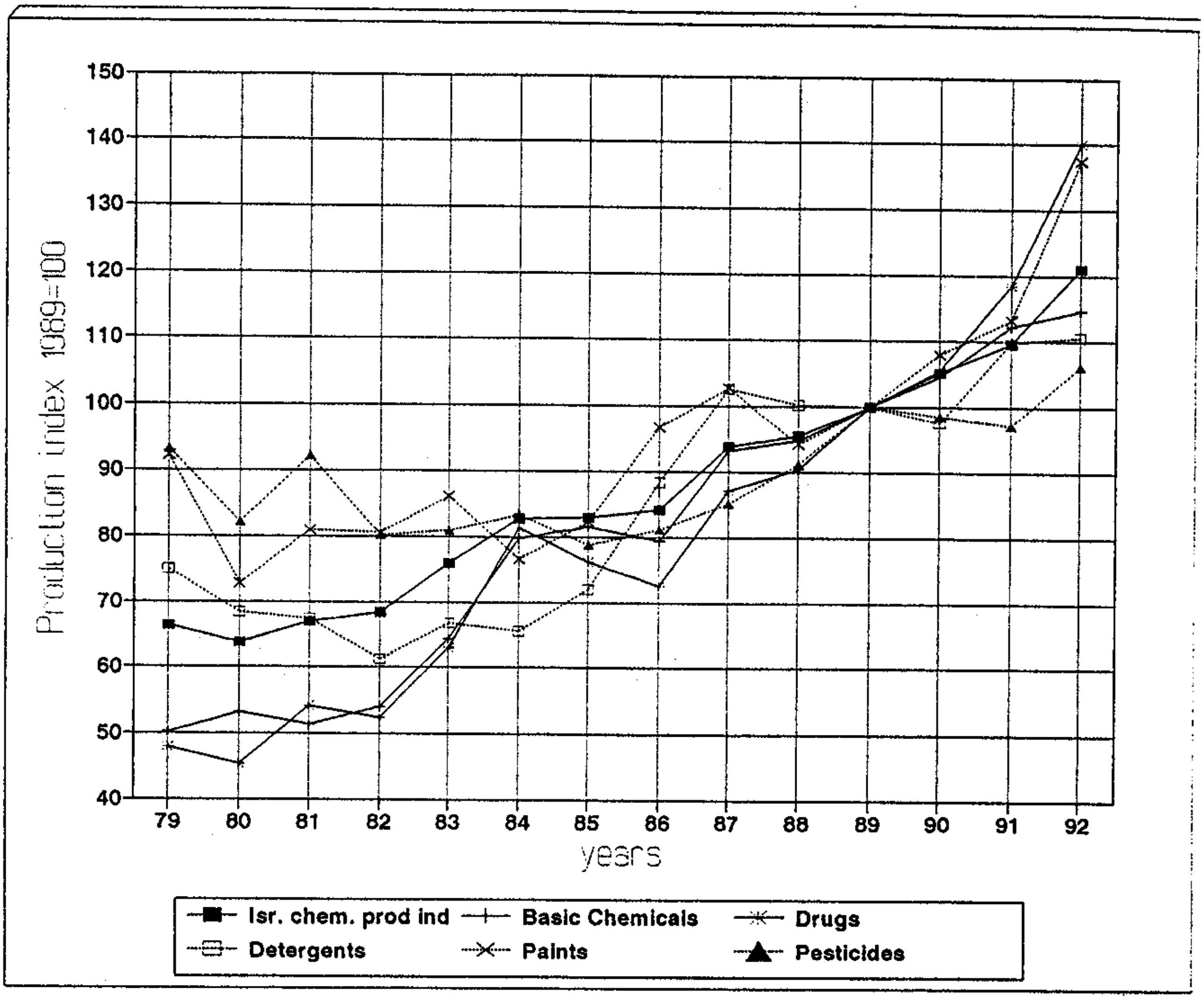
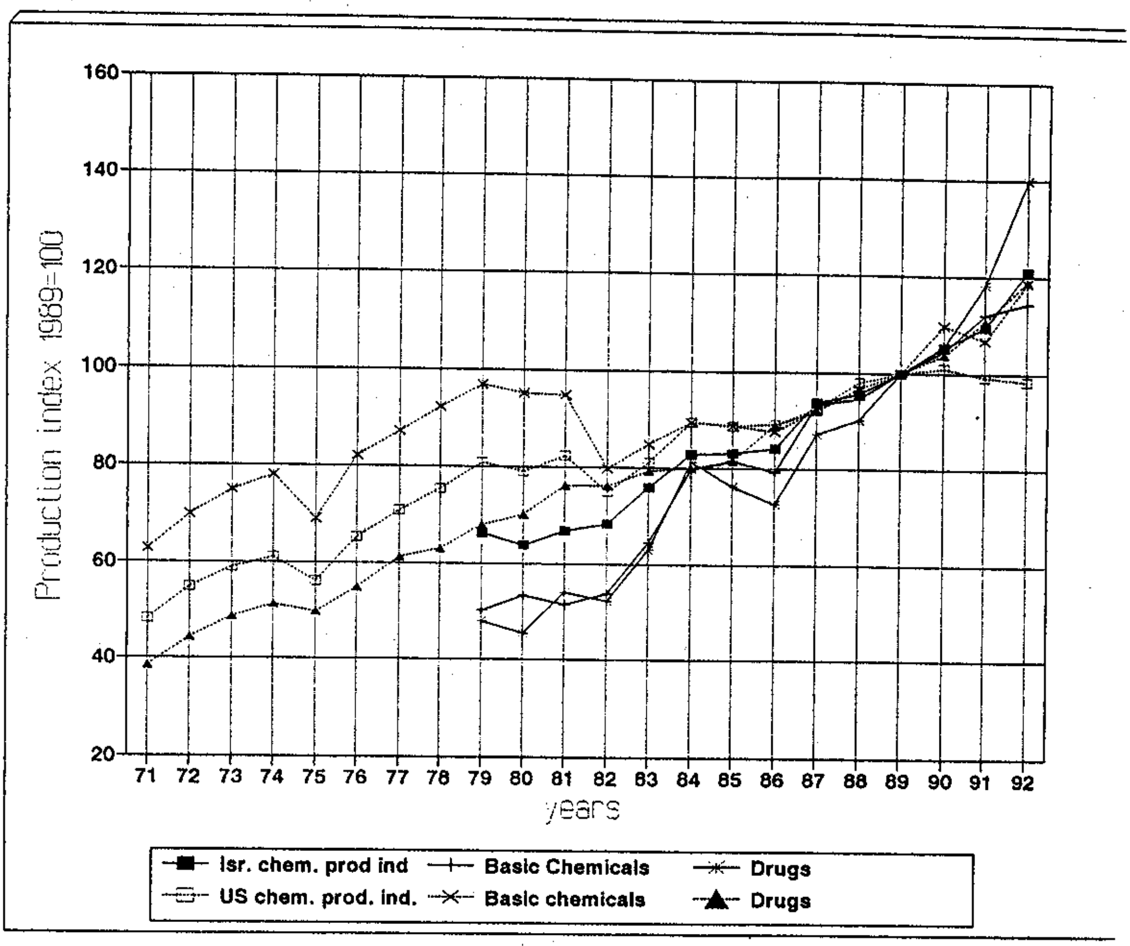


FIGURE 8: Comparison of the US and the Israeli chemical industries.



Using the official classification of segments, the exports by segment are presented in Table 27:

TABLE 27
Export by segments of the chemical industry in Israel in constant 1988 $MM (167)

Segment	1970	1980	1988	1989	1990	1991	1992
Evaporated salts	52	104	166	173	176	162	157
Other minerals	29	33	77	78	66	68	67
Basic chemicals	58	365	750	847	884	915	913
Drugs	23	42	94	62	81	106	156
Pesticides	32	125	115	44	37	33	36
Distillates	106	89	202	217	224	215	264
Total	300	758	1404	1421	1464	1502	1557

Note the abrupt change in the export of distillates in 1988, and in 1992. A change in the official classification transferred the major part of the pesticides in 1989 to basic chemicals (probably except formulations). The official definition of basic chemicals presents too wide a category to be of any practical use. It currently includes industrial chemicals, monomers, fertilizers, intermediates and pesticides.

4.7 Target markets

More useful information can be extracted from the data, when we arrange the local sales of the major chemical companies according to target markets (Table 28).

Oil refining that amounts to about 30% of the total sales is in its special target market here. The weight of intermediates (i.e. products sold to the chemical industry for further processing) is exceptional low, and probably accounts for the low added value of the Israeli chemical industry.

A similar separation by target export markets is shown in Table 29:

The agriculture markets dominate and comprise of 49% of the exports when the distillates are included in the total. Without the distillates, the agriculture markets account for 56% of the total exports.

TABLE 28

Local sales distribution of the Israeli chemical companies by target markets (1992) (in $M) (170)

	drugs	indus trial	buil ding	agricu lture	house hold	food	plas tics	text ile	ener gy
Biotechnology General	2								
Rekah	2								
Rad Chemicals	3								
Biological Industries	6								
Orgenics	3								
Chemada		1							
Chemagis	1								
Maxima		9							
Deshen Gat				8					
Taro	11								
Makor									
Serafon					13				
Vitamed	10								
B.G. Polymers			9						
Pazchem				12					
Rafa	12								
Fisher	9								
Nir Lat			9						
Explosives			15						
Kedem					16				
Pazkar			25						
Dor Chemicals		16							
Trima	21								
Frutarom						10			
Sharon Labs						14			
Luxembourg				4					
Dexxon	25								
Neca				27					
Carmel Chemicals							13		
Avco								23	
Zohar Dalia					29				
Interpharm					38				
Sano Bruno's									
Dead Sea Periclase		10							
Koffolk		22							
C.T.S.				3	4				
Abic									
Nilit									
Fertilizers & Chem.		7		60					
Gadot Petrochemical		7				5	6		
Carmel Olefins							83		
Tambour			128						
Electrochemical Ind.		9			1	2	50		
Agan				16					
Makhteshim		4		30	2		3		
Haifa Chemicals		17		17					
Rotem-Amfert		48		100					
Bromine Compounds									
Teva	246								
Dead Sea Works		7		10					
Oil Refineries		120							574
Total	351	285	186	260	129	34	140	28	574
% of 1987	18	14	10	13	6	2	7	1	29

TABLE 29

Distribution of Israeli chemical exports by target markets (1992) (in $M)

	drugs	indus trial	buil ding	agricu lture	house hold	food	plas tics	text ile	ener gy
Biotechnology General									
Rekah									
Rad Chemicals									
Biological Industries									
Orgenics									
Chemada		6							
Chemagis		6							
Maxima									
Deshen Gat									
Taro									
Makor		9							
Serafon									
Vitamed									
B.G. Polymers									
Pazchem				3					
Raffa				3					
Nir Lat			3						
Explosives									
Kedem									
Pazkar									
Dor Chemicals		1							
Trima									
Frutarom						8			
Sharon Labs						3			
Luxembourg				14					
Dexxon									
Neca									
Carmel Chemicals							12		
Avco								10	
Zohar Dalia					3				
Interpharm	38								
Sano Bruno's									
Dead Sea Periclase		32							
Koffolk		23							
C.T.S.									
Abic									
Nilit									
Fertilizers & Chem.				31					
Gadot Petrochemical		44				20	20		
Carmel Olefins							37		
Tambour			7						
Electrochemical Ind.							58		
Agan				115					
Makhteshim				139					
Haifa Chemicals		33		133					
Rotem-Amfert				169					
Bromine Compounds		150		150				29	
Teva	150								
Dead Sea Works				234					
Oil Refineries									239
Total (2017)	188	304	10	991	3	31	156	95	239
% of total	9	15	1	49	0	2	7	5	12

5. New directions and strategies of the chemical industry.

5.1 Introduction

By an analysis of performance data for the past two decades of the Western chemical industry, we have shown in the earlier chapters
that the chemical industry has been stagnating in the past decade. This was caused by a structural stagnation typical of a mature industry with slowly growing markets. The few companies that continued steady growth, had a good mix of products and a continuing presence in emerging markets.

The chemical industry in some developing countries, particularly in the Far East has grown more rapidly than the chemical industry in Western countries, due to expanding local markets, and no commitments to old technologies and equipment.

The growth of the chemical industry in Israel was intermediate between that of the Western countries and that of the Far East. However, the added value of the chemical industry in Israel is relatively low, due to a low degree of vertical integration.

The total sales of the chemical industry in Israel in 1992 were over $4 billions of which over $2 billions was exported, This amounted to a little over 20% of the Israeli industrial exports (excluding diamonds) (68). The total sales of the chemical industry in Israel in 1993 were $4.85 billions of which $2.2 were exported. The chemical industry in 1993 was comprised of 120 manufacturers, employing 21,800 people (127). The productivity per worker was about $ 222,500, more than for most Hi Tech industries.

The main internal markets for locally produced chemicals were : Energy, drugs, industrial (mainly intermediates for other chemical producers), agricultural, building and plastics. However, 50% of the exports go into the agricultural markets and another 27% into the intermediates and energy markets, with considerable sensitivity to fluctuations in these markets.

5.2 New directions of the US chemical industry

Due to the globalization of the chemical industry, and to the more available information on the strategies of the U.S. chemical industry, the U.S. chemical industry will serve here as an example of the international chemical industry.

The MIT commission on Industrial productivity (67) described the transformation of the US chemicals industry in the 80s as follows:

"Over the last century, the major driving force behind the industry's phenomenal growth has been a steady stream of technological innovations, encompassing the introduction of both new products and new process technologies.

The growth slowed by lessening opportunities for materials substitution in various end markets, structural changes in key consumer industries, rising competition from abroad, higher energy prices, lower productivity, decline in R&D intensity, sharp fluctuations in foreign exchange rates, growing overcapacity in commodity chemicals, and the growing array of environmental, health and safety regulations.

Industry's response was to shed off excess capacity, by shutting down, trading plants, or selling plants, the withdrawal from a strong position in the European chemical industry (while the non-US industry now controls more than 25% of the US chemical industry), active diversification into specialty chemicals, pharmaceuticals, biotechnology, advanced materials, and reduction in manpower"

"However, after a short optimistic interlude at the end of the 80s, the chemical industry in general failed to recognize that the hallmarks of today's global economic environment are diversity and change - and sometimes uncertainty and chaos." (R.J. Mahoney, chairman and CEO of Monsanto (2)).

F.P. Popoff, chairman and CEO of Dow, reviewed some of the mistakes made by the chemical industry (2): "The industry has long been guilty of operating with a market share mentality, investing in capacity expansions in advance of demand. We spend without any real attention to marketing fundamentals, exacerbating the ups and downs of a cycle, rather than trying to shave the peaks and fill in the valleys, we swing ourselves through these gargantuan cycles. This habit jeopardizes, among other things, the globalization that is essential to the chemical business. If you are at the bottom of a cycle, it is hard to be forward thinking in doing what is right in a global context. You tend to cut your losses and do things as you have traditionally done them because there is less risk and there is perhaps more short-term reward. I think economic volatility pulls your horizon closer, while success, profitability, and prosperity allow you to make the longer term investments that are fundamental to a global business."

The unprecedented challenges facing the chemical industry include (3) intensified international competition, escalating customer expectations, maturing markets, growing requirements for environmental stewardship and social responsibility, and potential costs of universal health coverage.

The approaches used by chemical companies to improve the bottom line, as detailed in Chapter 2 of this study were: Cost cutting, staff reductions, divestitures, leveraged buy-outs, mergers and acquisitions, strengthening existing production, move into higher added-value products, foreign trade and production, diversification, demerger, and reengineering.

Middle management people in chemical companies were subjected to a multitude of new 3 or 4 letter subjects, invented by business schools, such as : BMK, BPS, CFM, D&RA, HPWS, IWCT, PACE, MST, QFD, SCM, SDP, SVP, TQM, etc., in the futile hope that new management approaches would help managers control operations and reduce costs.

National commissions were set up to study and make recommendations.

The office of science and technology at the US White House has identified 22 national critical technologies (6). These technologies fall into 6 broad areas, of which 4 are relevant to the chemical industry:

1. Materials with properties that promise significant improvements in the performance of items produced and used by virtually every sector of the economy. (Such as electronic and photonic materials, ceramics, and composites.)

2. Manufacturing processes and technologies that can provide the basis for industry to bring a stream of innovative, cost-competitive, high - quality products into the marketplace.

3. Biotechnology and Life Sciences advances that will permit unconventional approaches to major problems in such diverse fields as medicine, agriculture, manufacturing, and the environment.

4. Energy and Environment related technologies which have the potential to provide a safe, secure, and enduring sources of energy and ensure that a healthy environment is preserved for the use of future generations.

The US National Academy of Engineering has come up with a new technology policy for national economic performance (7), which is summarized in Appendix I of this report.

The new White House policy unveiled recently (11) is:

A. Declarations:

1. Basic research is a national need.

2. The work of the scientific community must be more clearly relevant to human concerns.

3. The community should think in more creative multimedia ways of popularizing science.

B. Specific policies:

1. Review of Federal research programs to ensure that they relate adequately to national needs.

2. Raising combined public-private R&D spending from 2.6% of the GNP to 3%.

3. Stronger emphasis on multinational funding of large scale scientific projects.

4. Increase private sector involvement in improving academic research facilities and instrumentation.

5. Renewed emphasis on the already strong efforts to develop scientists and engineers among minority groups.

6. Making permanent the tax credit for research and experimentation in industry.

The American Chemical community realized that this policy may kill many sacred cows and rushed to put forward its own recommendations (12), which are summarized in Appendix II of this report.

The chemical industry, in general, is aware of the need for new strategies in order to provide business value and gain or maintain a market leadership position, such as (1):

1. Build core competencies that result in unanticipated products to satisfy real customer needs. These competencies must be built with more speed and agility than do competitors.

2. Invent and reinvent. Continually look for ways to breath new life and functionality into existing products, even in supposedly mature products.

3 Keep an open mind, not blind faith in past practices.

4. Support continued learning and reward people for building core competencies. A company's ability to improve existing skills and learn new ones before the competition is the most defensible competitive advantage of all.

5. Seek new opportunities. Real strategists won't look for a niche within an existing industry space. Instead, they will try to create a totally new space, not one yet filled by other players, that is uniquely suited to their core competencies, and provides value to the company and to its customer base.

Dow's chief suggests (2) that to compete, chemical companies need to seek out the location of the least expensive raw materials. They need to make the intermediates and the products where there is talented labor and proximity to markets, and to carry out technical service as close to the customer as possible. Companies have to look beyond their own internal goals and objectives. The industry should not ignore the external issues, such as competitiveness, trade, education, environment, technology, and corporate credibility that will determine the future performance. Industries need to grow in order to survive but development should not come at the expense of environment destruction.

Air Products (8) has shifted their strategic planning from business as usual to what are they doing to promote profitable growth. They are successful with products that apply proprietary technology. In many instances, their technological advantages do not come from basic scientific discoveries or strong patent positions, but from applied engineering that develops incremental advantages that can be moved quickly into the marketplace. They prefer products that are conducive to systems selling. They help customers improve their quality and productivity, and give them advantages that they can take into their markets.

A more international view was suggested by Porter (69): When firms from different nations form alliances, those firms based on nations which support true competitive advantage eventually emerge as the unambiguous leaders.

Competitive advantage is created and sustained through a highly localized process. Differences in national economic structures, values, cultures, institutions, and histories contribute profoundly to competitive success.

The main competitive forces are: The threat of new entrants, the threat of substitute products or services, the bargaining power of suppliers, the bargaining power of buyers and the rivalry among the existing competitors.

There are two basic types of competitive advantages:

1. lower cost: The ability of the firm to design, produce and market a comparable product more efficiently than its competitors.

2. Differentiation: The ability to provide unique and superior value to the buyer in terms of product quality, special features, or after sale service.

An important variable in positioning is competitive scope. A firm must choose the range of product varieties it will produce, the distribution channels it will employ, the types of buyers it will serve, the geographic areas in which it will sell, and the array of related industries in which it will also compete.

Innovations shift competitive advantages, Such innovations may be : New technologies, anticipating new or shifted buyer needs, perceiving the emergence of a new industrial segment, using a shift in input costs, or raw materials, energy or transportation availability, and adjusting to new government regulations.

In a recent interview during a visit to Israel Porter added (70): "The basis of national competitiveness nowadays is not local raw materials, number of workers, exchange rates or interest rates, but the ability of its business segment to innovate, to improve, to be efficient, to develop knowhow, and to utilize any knowhow.

The government should invest in education and infrastructure, to set standards for quality and for the environment, to encourage R&D by tax reductions, to subsidize the professional training of workers in industry, to be a wise, quality demanding, and leading buyer of local products and services, to legislate against and fight monopolies, and to help develop clusters with competitive advantages."

None of these concepts is new, and most firms are cognizant of their effectiveness, and pay lip service to them.

What has happened to innovations in the chemical industry? Ralph Landau summarized the number of major postwar commercial chemical developments (66):

In the 50s - 9.
In the 60s - 14.
In the 70s - 13.
In the 80s - 3.

Other estimates (9) were that the number of major product innovations declined from a peak of 22 in the decade of the 1940 to only two in the seventies (and the eighties).

The most important development in the chemical industry in the past decade is the production of polyolefins by metallocene single site catalysis. The products can have a narrow molecular weight distribution, and also makes possible control of long chain branching. Perhaps the invention of superabsorbent polyacrylate polymers can also be counted as a major development.

It has been suggested that the decline in major inventions a function of cost (10). The development of nylon cost $10 millions (1939 dollars), whereas the development of Kevlar by, the same company, cost $500 millions (in 1971 dollars).

5.3 Potential for growth of the Israeli chemical industry

Table 30 presents overall views of the economies and chemical production and added value for Israel, 5 developed countries and 2 developing countries. Each of the lines "Relative to Israel" was calculated from the line above it.

The comparison with Israel in the four "Relative to Israel" lines indicates that in order to reach the level of the developed countries per capita, the Israel chemical industry should grow by at least 50% and the chemical added value should grow by at least 200%.

The largest Israeli chemical corporation, Israel Chemicals, has announced its plans for the year 2000 to sell $400 millions in pharmaceuticals and $300 millions in advanced materials, which, if successful, would increase its sales by about 50% and its chemical added value by over 100%. Similar quantitative goals should be set by other companies. Achieving such goals requires fast action to take advantage of opportunities.

Table 30

The national chemical potential in 1992 (68,72)

Country		Israel	USA	Germany	Japan	Netherland	Switzerland	China	S. Korea
Population	MM	5	250	79	124	15	7	1134	43
GNP	$MMM	51	5445	1411	3141	259	219	416	231
GNP per capita	$MMM	9808	21700	22730	25430	17330	32790	370	5400
Relative to Israel			2.21	2.32	2.59	1.77	3.34	0.04	0.55
Added value	$MMM	9	1308	427	872	54	57	111	66
Added value/capita	$MMM	1731	5232	5405	7032	3600	8143	98	1535
Relative to Israel			3.02	3.12	4.06	2.08	4.70	0.06	0.89
Chem sales	$MMM	4	288	100	180	24	15	40	20
Chem sales/capita	$MM	769	1152	1266	1452	1600	2143	35	465
Relative to Israel			1.50	1.65	1.89	2.08	2.79	0.05	0.60
Chem added value	$MMM	1	156	56	87	7	9	14	6
Chem a.v./capita	$MM	192	624	709	702	467	1286	12	140
Relative to Israel			3.24	3.69	3.65	2.43	6.69	0.06	0.73

5.4 Opportunities and advantages

We live in a period of rapid change. The fall of communism has opened up both new markets and new competition. The peace process with our Arab neighbors, and the termination of the Arab boycott will make possible the purchase of knowhow that was previously unavailable to us at a reasonable price.

The traditional sources of competitive advantage, such as technology, capital and information can be obtained by anyone in the open market today.

Competitive advantage today depends (69) on the speed of getting a new or an improved product to market at a competitive price, on the quality of the product and on the speed of response to customers' needs. Customers value product quality and timely delivery.

Specific advantages of the Israeli chemical industry are:

High quality technical manpower, strengthened by the Russian immigration.
Familiarity with the use of high technology in operations.
A national characteristic: The ability to improvise and react quickly.
A growing number of experienced design and construction companies.
Increasing familiarity with the world markets.
Some relaxation of import restrictions in a few important markets.
Available internal and international credit.

Under-utilized research facilities in the country.
Government support of R&D.
Low interest loans and subsidies for plant construction.

Specific disadvantages of the Israeli chemical industry are:

Government control of most of the chemical industry.
Government control of the economy.
Very little R&D by most chemical companies.
Too much improvisation.

These can be overcome.

5.5 New approaches

We do not presume to know better than the management of chemical companies what is the best strategy and direction of growth of their specific companies.

In the above sections we have tried to show the viable strategies used by chemical companies. We have also shown that there is potential for growth on a relative basis, and that there is potential to increase the added value.

In the next three chapters we present 3 groups of potential areas for growth for the Israeli chemical industry:

Families of intermediates
Specialties.
New technologies.

We have attempted to show that opportunities in these areas exist, and it is up to the chemical companies to utilize the opportunities that fit their potential.

6. Identification of promising intermediate families

6.1 Introduction

The most attractive intermediates and chemicals products would be the chemicals with outstanding market growth rate. In order to avoid the cyclic nature of the market of many chemicals, we present here only those products, that have managed in 1993 (which was relatively a poor year for growth of chemical markets) or during the past 10 years, at least a 6% annual growth, in the U.S.

Table 31 shows the annual growth rate of those chemicals that had higher than 6% average growth rate over the past 10 years or in 1993 in the U.S.

Table 31

The annual growth rate for specific chemicals in the U.S. (71)

Organic Chemicals	Bisphenol A	Ethanol	Ethylene dichloride	2-Ethyl hexanol	Methanol	MTBE
1992-1993	7	6	18	-1	30	121
1983-93	7	-4	5	6	3	40

Organic Chemicals	Methyl chloride	MEK	Propylene glycol	Toluene	Vinyl acetate
1992-1993	-12	16	74	6	6
1983-93	8	1	6	1	4

Inorganic Chemicals	Ammonium Nitrate	Hydrogen	Nitric Acid	Nitrogen gas	Sodium Silicate
1992-1993	7	11	6	8	8
1983-1993	3	6	2	5	3

Minerals	Lithium
1992-1993	12
1983-1993	2

Plastics	Epoxy	Mela mine	Poly ester	Poly amide	Poly propylene	Polyethy lene HD
1992-1993	12	16	8	15	2	2
1983-1993	4	4	2	9	7	6

Synthetic Rubber	ABS etc.	Ethylene-Propylene
1992-1993	12	10
1983-1993	4	4

Misc.	Household products	Food products
1992-1993	6	8
1983-1993	2	-4

Agro-chemicals	Herbi cides	Ammonium Nitrate	Ammonium phosphate
1992-1993	6	9	15
1983-1993	-1	-2	7

6.2 Specific intermediates families

Following are some details of eight intermediates and their derivatives, which we have identified as having a good fit with the Israeli chemical industry and with a potential for growth.

These eight intermediate families are synthesis gas mainly for methanol and its derivatives, sulfur derivatives, derivatives of ethylene, propylene, butanes, benzene, xylenes and chlorine.

The recent consolidation of most of the petrochemicals industry in Israel into one group makes possible a faster growth of the petrochemicals industry which involves six of these eight intermediate families.

Table 32 shows the production capacity of 10 commodity intermediates, including many of the intermediates discussed in this chapter, by the producing companies (101-105).

6.2.1 Synthesis gas, methanol and its derivatives (73-77).

The production of some of these compounds in Israel is based on relatively expensive naphtha reforming. However, if natural gas from Egypt, or the Gulf states becomes available at competitive prices, derivatives based on synthesis gas will be competitive in the world markets.

The world production of methanol in 1993 was over 21.5 million tons, with high capacity utilization of the plants due to the sharp increased demand for MTBE, which may soon pass the production capacity of formaldehyde and acetic acid, the current main derivatives of methanol.

Methanol and MTBE are produced in Israel, mainly for local consumption, but acetic acid is not produced. The bottleneck for more MTBE production in Israel is the limited availability of butylene and not of methanol. However, for a large MTBE plant there will be justification to produce butylene from butane.

Acetic acid is attractive as an intermediate, since it can lead to families of derivatives.

A complex of such intermediates was studied recently by a company in Israel, with reasonable preliminary results.
The complex was based on the following items: 15,000 tpy polyvinyl acetate
5,000 tpy polyvinyl alcohol
2,500 tpy polyvinyl butyral
1,250 tpy ethyl acetate
10,000 tpy cellulose acetate

TABLE 32
The capacity of selected chemicals in '000 tpy in 1992

The capacity of selected chemicals in '000 tpy - 1992										
	Styrene	MTBE	Ethylene glycol	Acrylonitrile	Acrylic acid	Terephth. acid	Titanium dioxide	Acetic acid	Butadiene	Methanol
Air Products										225
Amoco						3035			75	
Asahi				260	18					
Ashland										475
BASF	550			220	682			40	180	240
Bayer							125		120	
Beaumont										1000
Borden										840
BP	275			500				450		
Buna	100		654						120	
Cape Horn										760
China-American						1100				
Cytec				160						
Dow									170	
DSM				170					110	
DuPont				170		690	640			
Eastman						250		545		200
Elf					220				110	
EniChem	60			180		90		70	365	
Enron										450
Erdol			150	280					250	
Exxon		40							375	
Formosa					65			150		
Fortier										570
Georgia Gulf										500
Hankook							36			
Hoechst			100	100	170			1240		2000
Huels	300	150			60			40		
ICI			65			550				500
Idemitsu					50					
Intercontinental						200				
Ishihara							200			
Kemira							280			
Kerr-McGee							100			
Kronos							401			
Leuna										650
Lindsey		100								
Lucky					65					
Lyondell									295	800
Methanor										760
Mitsubishi				115	110	670				
Mitsui				60		550				
Mizushima						155				
Monsanto				225						
Nanjing				170		450				
Naphtachimie									70	
Nippon Shokubai					150					
Nitto				90				380		
Novacor										900
Oita					60					
OMW/DEA		60							47	
Oxychem									165	
PCK				70						
Pemex				150					83	
Pequiven										1440
Pertamina						225				
Petkim						70				
Petrocel						440				
Quantum								410		725
Quantum										
Reliance Ind.						230				
Rhone-Poulenc							125	470		
Rohm and Haas					275					
ROW	420									200
Sachtleben							80			
Samnam						280	55			
Samsung						610		150		
Saudi Methanol										2070
SCM							450			
Shanghai						250				
Shell									200	
Showa Denko				50				260		
Sterling				330				275		
Sumitomo				50	48					
Sunkyong						250				
Texaco									270	
Texaco Olefins									508	
Ti-West							54			
Tioxide							484			
Toray						170				
Union Carbide					85			165		
Total	1705	370	969	2920	1915	9945	2692	3945	2735	15295
	partial	partial	partial							partial
Price $ per ton				625	1600	600	1750	450	300	400
Total value $ bill.				2	3	6	5.5	2	1	6

Additional derivatives of acetic acid include: Chloroacetic acids
Acetyl chloride
Amino acids (by fermentation)
Acetic and acetoacetic esters
Sodium and ammonium acetate
Cellulose propionate and acetate-butyrate
Carboxymethyl cellulose
Acetamide and dimethylacetamide (DMAC)
Salicylic acid

An important outlet for acetic acid is for the production of terephthalic acid (TPA), where it serves as a liquid-phase oxidation solvent.

Other compounds based on CO and methanol include formic acid and its derivatives, formamid and dimethyl formamide. Formic acid is used in the metal, textile and leather industries. Formamide is an important intermediate, made from CO and ammonia. It is used for the production of cyanides, imidazols, triazins and pyrimidine, and also as a solvent for spinning various polymer fibers.

Dimethylformamide is produced from CO and dimethylamine. It is a versatile apriotic solvent used in textiles, polymers casting, aromatic extraction, solvent for gases and electrolytes in galvanization baths, paint remover and cleaner. Its major use is as solvent for acrylic fibers and polyurethanes. The world market in early eighties for dimethylformamide was about 250,000 tpy (73).

6.2.2 Sulfur Derivatives (95)

The leaders in this market are still companies that have developed the process technology. For example, BASF, the developer of the vanadium catalyst for the contact process, is a major producer of sophisticated organic sulfur products, such as 4-amino sulfanilanilide or 3-amino-2-hydroxy-5-nitrobenzenesulfonic acid.

Sulfuric acid production, which represents 75% of the sulfur used by the chemical industry, is dominated by the fertilizer industry.

The availability of sulfur in Israel as a by-product of the refineries or as imported on a large scale by the fertilizer industry presents an opportunity to produce sulfur derivatives.

In the world, only 3 - 5% of the sulfur compounds (by weight) is consumed by the dyes and pigments industry, but these represent sales of sophisticated products with a total products value value close to that of the much larger fertilizer industry.

As an illustration of what a single company can achieve in this area, we can take the Swiss company Saurefabrik Schweizerhall palette of sulfur products:

Inorganics:
Thionyl chloride
Sulfuryl chloride
Chlorosulfonic acid
Sulfur dioxide
Oleum
Sodium hydrogen sulfite

Organics
Dimethyl sulfate
Toluenesulfonic acid methyl ester
3-Chloro-4-methyl-benzenesulfonyl chloride
N,N-Dimethylethylamine sulfur trioxide complex Pyridine sulfur trioxide complex N,N-Dimethylthiocarbamoyl chloride 2-Aminoethyl-2-hydroxyethyl sulfide

Another example is the range of fine sulfur chemicals produced in Japan by Sumitomo Seika:
Thiols
Thiophenol
Thioanisole
Tribromomethyl phenyl sulfone
Diphenyl sulfide
Diphenyl disulfide
p-tert-Butylthiophenol
4-Chlorothiophenol
Thiodiphenols
4,4-Thiodiphenol
Bis (4-hydroxy-3-methylphenyl)sulfide
Thiophenes
2,5-Bis(5-tert-butyl-2-benzoxazolyl)thiophene Aliphatic sulfur compounds
Methyl mercaptan
2-(Methylsulfonyl)ethanol
Sulfolane
3-Sulfolene

6.2.3 Ethylene and derivatives (71,86,87)

The major derivatives of ethylene, polyethylene and ethylene dichloride, are manufactured in Israel. The production of the third important derivative, ethylene oxide, accounting in the U.S. for about 15% of the ethylene demand, is rather stagnant, due to the decrease in demand of its main downstream product, ethylene glycol antifreeze. Ethylene glycol may be of interest only if a large plant for the production of polyethylene terephthalate is considered. Ethyl benzene is discussed in the section on benzene derivatives.

Ethylene dibromide was an important commodity chemical produced in Israel till the ban on its use due to its carcinogenous properties closed its markets.

There could be a commercial opportunity to build. next to the ethylene plant, plants for a few of the smaller scale derivatives of ethylene, such as:

Vinyl acetate	2 % of world ethylene demand
Ethylene-propylene rubber	1 % of world ethylene demand

The derivatives of vinyl acetate are polyvinyl acetate, polyvinylbutyral, and polyvinyl alcohol. Ethylene-propylene rubber is used mostly for automotive applications, wire and cable jacketing, and impact modifiers for plastics.

Although considered a mature product, ethylene-propylene rubber has grown fast last year (Table 31.)

Smaller scale derivatives of ethylene are:

Ethylenediamine	used for fungicides and as a chelating agent.
Ethyl and vinyl toluene	used for unsaturated polyesters.
Ethyl anilines	used for dyes, pharmaceuticals, and pesticides.
1,4-hexadiene	used for ethylene-propylene terpolymers.
Aluminum alkyls	used for initiators and catalysts.
Ethyl amines	used for rubber chemicals and as inhibitor.
Ethyl ether	used for pharmaceuticals and as a solvent.
Propionaldehyde	used for cellulose plastics or as grain preservatives.
Propionic acid	used for cellulose plastics or as grain preservatives.

6.2.4 Propylene and its derivatives (88-91)

Currently, all the propylene production in Israel, is dedicated to polypropylene production, and if more propylene were available, it would probably be used for the same purpose.

In the leading industrialized countries 50 to 60% of the propylene is used for acrylonitrile, propylene oxide and propylene glycol, cumene (leading to phenol and acetone), isopropanol, oxo alcohols and acrylic acid.

Acrylonitrile production is driven mainly by the textile and polymer industries. Propylene glycol and phenol are used for thermosetting resins (which are produced in Israel). The other ethylene derivatives products are intermediates, directed to different branches of chemical industry.

The most promising propylene derivative is acrylic acid. It has one of the highest growth rates, both in the West and in the East, and continued to grow about 7% a year for several decades. Water based acrylates are replacing other solvent based esters. The high water absorbing polyacrylates for diapers are one of the best inventions of the past decade.

Acrylic acid is produced currently by oxidation of propylene in two stages, with acrolein, the allyl aldehyde, as an intermediate. Each stage employs a different catalyst and with different operating conditions.

The U.S. market for acrylic acid represents today about 40% of the global capacity, its development over last three decades is shown in table 33.

Table 33

The development of the U.S. market and price for acrylic acid.

year		1963	1973	1983	1993
market	M tons	11	60	333	600
price	$/ton	880	528	1300	1600

Due to its attractive market, overcapacity in production facilities for acrylic acid followed and is predicted to persist till 1996. The production of acrylic acid and its derivatives is limited to a very few countries, probably because of the need for integration. Most major producers of acrylic acid and its derivatives in the Western hemisphere such as BASF, Hoechst-Celanese, Elf-Atochem, and Rohm & Haas have their own in-house propylene.

In Israel the top level - propylene, and the bottom levels - diaper production, and acrylic coatings exist. It may be worthwhile to fill the intermediate stages.

6.2.5 Butanes and their derivatives (80,87 106-108).

The C4 stream in refineries is composed of butanes, butenes and butadiene. Each of these species can be converted to the other if market and economic conditions justify it.

Butane is used as a fuel for homes, and occasionally, as a feedstock for synthesis gas. The main chemical use of butane used to be dehydrogenation to butadiene. However butadiene obtained as a by-product of olefins production has replaced most of the demand for dehydrogenation. Liquid phase oxidation of butane to acetic acid is still used in a few old plants.

An important use of butane is for the vapor phase oxidation to maleic anhydride and maleic acid, which has replaced the older route, using benzene as the raw material. A plant for 10,000 tpy of maleic acid was planned in Israel, but was not built.

The isomers of butene are: 1-butene, cis-2-butene, trans-2-butene, and Isobutylene (2-methyl propene). The most important derivative of butenes and the fastest growing is MTBE from isobutylene and methanol. MTBE is also manufactured in Israel, but its production is limited by the current availability of isobutylene.

The most important derivatives of mixed butenes are: sec-butyl alcohol, which is easily converted to methyl-ethyl ketone (MEK), butyl elastomers (including butyl rubber) and polybutenes. Minor derivatives are: Butylated phenols and cresols (antioxidants), Tert-butylamine, tert-butyl alcohol, tert-butyl mercaptan, di- and tri-isobutylaluminums, butylene oxide, p-tert-butyltoluene, pivalic acid and methallyl chloride.

Most of the demand for butadiene (85% in 1986) was for synthetic rubber. The global synthetic resin capacity was 9.5 million tons in 1993, The distribution of the synthetic rubber production is shown in Table 34.

Table 34

Synthetic rubbers production in percent of the market share in 1993

Styrene-butadiene	57
Polybutadiene	16
Butyl-polyisoprene	9
Ethylene-propylene	9
Nitrile	5
Polychloroprene	4

Butadiene is a component of 73% of the market for synthetic rubber. Synthetic rubber takes 60% of the total market for rubber.

The main non-rubber use of butadiene is for adiponitrile, which in turn is used for the production of hexamethylenediamine, one of the two precursors of nylon 6,6. Adipic acid, the second precursor of nylon 6,6 can also be made from adiponitrile, although this route is rarely used currently. Adiponitrile can also be made from acrylonitrile (A Monsanto process).

A new process for butadiene to vinyl cyclohexene to styrene has been piloted by Dow, and will soon be offered for licensing.

A plant for maleic anhydride, maleic, malic and fumaric acids, is a good fit with the current petrochemical industry in Israel. Increasing isobutylene and MTBE production are inevitable. MEK production may also be attractive. If the capacity of cracking to olefins is increased, there will be an economic justification to separate the butadiene (Currently it is hydrogenized), and use it for downstream products, such as Nylon 6,6.

6.2.6 Benzene and its derivatives (71, 78-80)

Heavy downstream demand for styrene and other derivatives and supply problems upstream have recently driven benzene prices up by over 10%. The supply situation of benzene was always associated with the demand for aromatics for the gasoline pool and to the most recent estimates of its toxicity. World capacity production location is shifting. Asia/Pacific accounts for 24% of the world production capacity, about the same as for Western Europe. The main recent capacity increases have been in Korea, Taiwan, Thailand and Singapore.

The present distribution of the 1993 total world production of 22.7 million tons of benzene is shown in Table 35.

Table 35

The distribution of the world production of benzene by markets.

Product	Market Share (%)	Used for
Ethylbenzene	53	styrene, polystyrene, ABS, SAN, rubbers.
Cumene	17	phenol, phenolic resins, acetone.
Cyclohexane	15	caprolactam, nylon 6.
Nitrobenzenes	5	aniline, dyes, drugs.
Alkyl benzene	4	detergents.
Chlorobenzenes	2	dyes, solvents, pesticides.
Maleic anhydride	1	polyesters, alkyd resins.

The best fit with the current Israeli chemical industry would be ethybenzene, styrene, cumene, cyclohexane and chlorine derivatives.

Phenol and acetone can be produced from cumene. Phenol is used in Israel with formaldehyde and melamine for phenolic plastics. Phenol and acetone are used for the production of bisphenol A, for which the demand in Israel has risen. It leads to epichlorhydrine and to fast growing epoxy resins.

Cyclohexane, is used to produce caprolactam, a precursor of Nylon 6.

Chlorobenzene derivatives include:

Chloronitrobenzenes	Intermediates for dyes and herbicides.
3,4 dichloroaniline	Intermediates for dyes and herbicides.
Dichlorobenzenes	Intermediates and disinfectants.
1,2,4,5-Tetrachlorobenzene	Intermediates, bactericides.

6.2.7 Xylenes and their derivatives (80, 92-94)

The fast growth rate of the demand for saturated polyesters in the Far East caused an acceleration of all the production chain of p-xylene to terephthalic acid to saturated polyesters. 68% of all the world demand for the terephthalic acid are concentrated in the Far East and while the average world growth rate is about 7%, it is higher in Asia. The annual growth rate of p-xylene is 5.5%, the highest of all common monomers. Since only 45% of the world p-xylene production is in the Far East, significant amounts are imported.

Gadot Petrochemicals (Now Gadiv) produces about 60,000 tpy of xylenes, but only 15,000 tpy of o-xylene is converted to chemical products (mainly phthalic anhydride). The remainder is exported.

The production of terephthalic acid with polyethylene terephthalate was considered in Israel several times but was rejected, mainly because of the consideration of inadequate supply of raw materials.

A terephthalates plant will require large quantities of acetic acid as solvent and can motivate a decision to produce acetic acid.

6.2.8 Chlorine and its derivatives (81-84)

Despite recent attacks on chlorine by environmentalists, its global production continued to grow.

The main demand is in the following markets:

- Polyvinyl chloride.
- Pulp and paper bleaching.
- Water treatment.
- Chlorinated solvents.
- As a synthesis and oxidation intermediate.
- Production of bromine.

Table 36 shows the main chlorine derivatives, the production capacity for many of the derivatives in the US and in Japan, and which derivative is manufactured in Israel.

Ethylene dichloride is by far the dominant intermediate produced from chlorine, leading to PVC. The growth rate of the use of this polymer in developing countries is high.

Due to environmental pressure, a shift has begun from the use of chlorine for bleaching and water treatment to chlorine dioxide, changing little the overall demand, with minor use of hydrogen peroxide as a more environmental benign chemical.

Table 36

The production of chlorine and its derivatives in the US, Japan and Israel.

	Chlorine derivatives Produced in thousand tons/year in		
	USA	Japan	Israel
	1992	1993	
Chlorine gas	5000	4000	+
Allyl chloride			
Amyl chloride			
Carbon tetrachloride	180	45	
Chlorinated isocyanurates			
Chloroanilines			
Chloroantraquinone			
Chlorofluoro hydrocarbons			
Chloroform	230		
Chloroprene		70	
Chlorosulfonic acid			
Dichloropropane			
Dichloropropenes			
Epichlorhydrine		100	
Ethyl chloride	50		
Ethylene dichloride	7000	2300	+
Methyl chloride	390	110	
Methyl chloroform	320		
Methylene chloride	160	90	
Methallyl chloride			
Perchloroethylene	110	45	
Phosgene			+
Trichloroethane		40	
Trichloroethylene		50	
Aluminum chloride		60	
Antimony pentachloride			
Antimony trichloride			
Arsenic trichloride			
Bismuth trichloride			
Chlorine trifluoride			
Ferric chloride			
Hydrochloric acid	1300	700	+
Hypochlorous acid			+
Iodine trichloride			
Iodine monochloride			
Mercuric chloride			
Mercurous chloride			
Molybdenum pentachloride			
Phosphorus oxychloride			
Phosphorus pentachloride			
Phosphorus trichloride		15	
Sodium chlorate	250	30	+
Sodium chlorite		3	
Stannous chloride			
Sulfur dichloride			
Sulfur monochloride			
Sulfuryl chloride			
Titanium dioxide		570	
Titanium trichloride			
Silicon tetrachloride			
Zinc chloride		12	

In Israel, three companies erected, in the early fifties, chlorine plants dedicated to the production of bromine, EDC and DDT respectively. The first two have been expanded and modernized and still serve their original purpose. The new magnesium plant, under construction at the Dead Sea, will more than double the current production of chlorine.

There is a good technological base to expand the chlorine chemistry to more sophisticated intermediates and to reach the downstream consumers. This has been done to some extent in the field of pesticides, but not in other potential areas, such as pharmaceuticals, polymers (other than PVC), ceramic and electronic chemicals, metallurgy, paints, etc.

The only outlet large enough for the potential excess chlorine is titanium chloride/ titanium dioxide. If the HCl byproduct could be used in Israel for phosphoric acid production, a process in which Israel is the world leader, a world scale titanium dioxide plant can be competitive.

Of the organic chlorine derivatives, the more promising intermediates are those used as polymer intermediates, such as epichlorhydrine, and chlorinated isocyanurates, and also silicon tetrachloride, and perhaps chloroprene.

The production capacity of sodium chlorite, which was considered in Israel by two companies is increasing in the world, and sodium chlorate is another prospective derivative.

7. Specialties

7.1 Introduction

Specialties represent low volume, high value-added products for pharmaceutical, foods, processing semiconductors or treating cooling water and a variety of other markets (46,47). Moving into this niche requires a highly responsive research staff. Company strength should be in marketing rather than in production. Strategic business units best suited for specialties are small, entrepreneurial, and market oriented. Large firms moving into specialties had to decentralize at least part of their hierarchy in order to succeed in this business. Profits may be substantial, but so are the risks.

True specialties make up only one sixth of the world market for industrial chemicals (47) - far too little to accommodate all the would be entrants. Advanced companies are therefore moving beyond chemicals into specialty materials, into instruments, complete systems of product plus equipment, and fabricated products and even services.

The downstream era will require a new breed of chemists and chemical engineers. They will have a broader view of science and technology than their predecessors and wider interests. There will be fewer specialists and more generalists, preferably with interdisciplanry experience (47).

The term differentiated products is occasionally used instead of specialties. Differentiated products are defined as (45):

1. Generally impossible to characterize by chemical formulas, or a statement of chemical content or origin alone.

2. Produced with real differences between suppliers, or marketed with imputed differences, such as the supplier's' reputation.

3. Often used only in a few applications.

4. Sold to performance specifications for what they do.

Regardless of the product line, the characteristics of the chemical specialties company are (43):

Hundreds of products - each with its own basket of different ingredients, each sold on the basis of performance rather than on formula or physical characteristics.

A myriad of low volume applications, sometimes called niches, that change as the customer's technology and manufacturing process changes. Product life cycle are less than five years.

High dependence on the relationship between sales staff and customer, and high reliance on speed and flexibility to satisfy customer problems.

Another view of the characteristics of specialized chemicals companies is (44):

Dominant companies but not in the public, anti-big-business eye.

Outward-looking and customer-need-oriented, enabling these firms to be in tune with the times.

Low capital investment.

Low factory labor cost.

Chemicals' cost is a small percentage of end system cost.

Multifunctional (flexible) manufacturing facilities - usually batch type.

Concentration on one type of product or market, allowing top management to have an intimate knowledge of its business.

Cumbersome EPA and TOSCA regulations which make it more difficult for smaller competitors and often poses product opportunity.

A specialty chemicals business must invest in technology, in people and in time (42)." Only when we understand our customers' business as well or better than they do are we likely to succeed. Developing a successful specialty chemicals business comes at a cost. We largely forego economics of scale, and the skilled, dedicated people needed to understand the markets in depth and to service our customers are expensive."

Sartomer Co, a unit of ARCO Chemical Co, in west Chester, Pa, is an example of a small company with a highly specialized line of chemicals (41). It manufactures functional acrylic monomers and oligomers which are used to modify formulas in coatings and other products which utilize polymeric components. Their line has 300 items, and some may be produced in as many as 30 different grades according to the end use. the grades can vary in purity and in the amount of inhibitor present. When Sartomer is presented with a new set of specs by a customer, it often produces a customized specialty and supplies it so rapidly that the customer, unaware of the research involved in filling his order thinks that he is purchasing off the shelf.

Potentially new products beyond conventional chemicals are (9):

Agriculture and food: Animal growth hormones, Food preservation, Integrated pest management services, Seeds and cloned plants.

Ceramics: Advanced glasses, High temperature fibers, Magnetic materials, optical fibers, piezo- and ferro-electrics, sensors, shock resistant structural parts.

Composites: Carbon-polymer, ceramic-ceramic. ceramic-metal, metal-polymer.

Electronics: Electrochromics, liquid crystals, light emitting diodes, plasma systems, injection molded circuit boards, photovoltaics materials, radiation shielding, non-silicon substrates.

Energy production and storage: Advanced batteries, fuel cells, hydrogen production from water, imaging materials, solar energy materials, superconductors.

Health care: Artificial blood, artificial organs, medical and diagnostic instruments, prostheses, tissue culture processes.

Metals: Amorphous, clad, magnetic, superconducting, memory alloy.

Military and space: Composites and advanced materials, radiation resistant materials, stealth materials.

Surface modification: Intercalation, Ion implantation, stealth coating, synthetic diamond coating, vapor deposition.

Miscellaneous: Artificial intelligence systems, biosensors, toxic waste management.

Fast growing specialties are (38) electronic chemicals and diagnostic aids, reprographic chemicals, plastic additives and high performance adhesives. Electronic chemicals generally are specified in ultra high purities and require close coordination with the customers.

Analyst Enrico T. Polastro of ADL Brussels estimates the value of worldwide fine chemical sales in the range of $26 billions to $34 billions (40). This includes bulk active ingredients as well as intermediates for end uses such as drugs and pesticides.

Table 37 shows a summary of the estimated markets for a number of specialties of interest, and table 38 shows the 1993 sales of specialties in the U.S.

Table 37

Estimated markets for a number of specialties

Subject	Market	Year	$MMM	Ref.
Biochemicals	World	1992	5.9	(36)
Catalysts	US	1985	0.995	(55)
Catalysts	US	1990	1.12	(55)
Catalysts	US	1990	2.11	(57)
Catalysts	World	1990	5.984	(57)
Catalysts	World	1993	8	(58)
Catalysts	World	1994	5.5	(59)
Catalyst	World	1994	7.9	(60)
Catalysts	World	1995	7.888	(57)
Catalysts	World	1998	10.7	(58)
Controlled Release Fertilizers	US	1990	0.175	(39)
Custom Mfg	World	1993	26-34	(63)
Drugs	World	1993	15-17	(40)
Environment	World	1990	200	(28)
Environment	World	1991	270	(27)
Environment	World	1995	300	(26)
Environment	World	1996	399	(27)
Environment	World	2000	300	(28)
Fine Chemicals	World	1993	26-34	(40)
Flavors	World	1993	4	(65)
Fragrances	World	1993	5	(65)
Membranes	World	1991	2	(51)
Superconductors	World	1992	1.5	(29)
Superconductors	World	1993	1.5	(28)
Superconductors	World	2000	8-12	(28)
Superconductors	World	2010	60-90	(28)
Superconductors	World	2020	150	(29)
Superconductors	World	2020	150-200	(28)

Table 38

The U.S. sales of specialty chemicals (116).

Category	1993 sales $MM	Profitability	Projected annual growth %
Pesticides	6,200	Average	2
Industrial coatings	5,780	Average	3
Industrial cleaners	5,300	Average	2
Electronic chemicals	4,700	High	7
Plastics additives	2,900	Average	5
Food additives	2,840	Average	5
Water management	1,900	High	5
Adhesives	1,800	High	7
Catalysts	1,800	Average	3
Flavors & fragrances	1,750	High	5
Photographic chemicals	1,500	High	6
Lubricants	1,300	High	8
Dyes	1,200	Low	4
Pigments	1,200	Average	3
Biocides	800	Average	4
Oil-field chemicals	800	Average	4
Paper additives	700	Average	4
Specialty surfactants	600	Average	5
Total	**66,695**		**6**

In Israel several companies have long term experience with specialties. Some, such as the pesticides manufacturers have been active in the international market. However, pesticides, herbicides and fungicides are expected to grow slowly (37). A few Israeli companies, such as paints and detergent manufacturers, have been producing mainly for the local market. Many young chemical companies in Israel have started in the specialty markets. In the next sections we attempt to highlight a few specialty areas that have potential for the Israeli chemical industry.

7.2 Promising specialty families

7.2.1 Flame retardants (114,115)

Flame retardants are plastic additives. Plastic additives have a $10 billion world market (including about $3 billion in the U.S.). Half of that market is bulk additives, such as PVC plasticizers and stabilizers, mineral fillers, etc. The rest are true specialties.

The U.S. plastic additives market, excluding fillers, in 1993, is shown in table 39.

Table 39

The major U.S. plastic additives markets in 1993 (in $MM) (109-111)

Type of additive	Value $MM
Specialty flame retardants	350
Lubricants	290
Specialty plasticizers	270
Reactive additives	190
Antioxidants	145
Mold-release agents	90
Ultraviolet stabilizers	55
Coupling agents	45
Antistats	25
Antifogs	7
Compatibilizers	6
Antimicrobials	5
Total	**1478**

Flame retardants, obviously, are the most important group.

Flame retardants can be classified as halogen-based, phosphorus-based, and inorganic chemicals. Halogen-based bromine products and aluminum hydroxide have the largest shares in terms of quantity. The major brominebased products by volume are tetrabromo-bisphenol-A (TBBA), decabromodiphenyl oxide (DBDPO) and TBA epoxy oligomer-polymer. In 1992 the DBDPO retardant was attacked on environmental grounds in Europe, and the demand for low toxicity flame retardants has expanded. Alternative candidates for DBDPO are brominated epoxies, TBA epoxy oligomer-polymer, TBA polycarbonate oligomer, etc.

Contradictory opinions about the safety of brominated flame retardants were voiced by Lonza and by Ethyl Corp. Lonza started in 1992 a facility in Austria to produce a new magnesium hydroxide product called Magnifin (112). Its flame-retarding reaction is based on the endothermic decomposition to oxides and water, supposedly without any corrosive or toxic by-products. Two of Israel Chemicals' subsidiaries, Dead Sea Periclase and Bromine Compounds, will jointly build a plant producing flame retardants based on magnesium hydroxide (113).

Bromine Compounds also made a deal with Great Lakes Corp. for joint production of TBBA, currently produced by both companies (111).

EniChem is close to introducing a new glycol terephthalo phosphinic copolymer, and DuPont's subsidiary M-Cap is developing microencapsulated formulations.

Bromine Compounds, which has been active in this field for many years, can become a world leader in flame retardants if it pursues an aggressive R&D operation in this field.

7.2.2 Catalysts

Most catalysts can be considered as specialty inorganic chemicals.

It was estimated (61) that in the US the total value of products requiring catalysis in their manufacture is about $900 billions per year. (About 17% of the GNP), of which the chemical and the refining industries produce about $150 billion of goods.

The global catalyst market is estimated at $5.5-$7.9 billion (59,60), and is expected to reach $10.7 billion by 1998 (58).

Currently (58) the main catalyst markets are: $3 billion for chemical processes, of which the 1994 polymerization catalyst market was estimated (85) at $1.15 billion, $3 billion for environment and $1.9 billion for refining. The fastest expected growth is for the environment market.

The highest value catalysts are a variety of zeolite based catalysts for FCC. (57) The major producers are: Davison Chemicals (40% market share), Akzo, Engelhard and Katalystics.

Estimates of sales of catalysts are occasionally correct. U.S. sales of process catalysts, used in refineries and chemical processes, reached 4.86 billions lb in 1985, valued at $955 millions, and was expected in 1986 to reach $1.12 billion in 1990 (55). The largest volume was for alkylation (4.265 billions lb in 1985 (mostly acids)) with catalytic cracking at 370 million pounds in second place. The largest values were for catalytic cracking ($250 million in 1985 and estimates of $275 millions in 1990, and actual sales of $280 millions (56)), and alkylation ($160 million in 1985 and estimates of $177 million in 1990, but the actual sales in 1990 of sulfuric acid for alkylation reached $220 millions (56)). Polymerization catalysts were expected to reach $220 millions in 1990.

The most successful new catalysts are the metallocenes. It is expected that new and expanded uses will be developed for metallocenes (85) and it is estimated that the sales of metallocene based polymers in 2000 will reach $21.6 billion. Although production costs are the same as for the old technology, Dow plans to sell the new narrow size distribution polyolefins at 2-3 times the price of the current products (54).

Another conventional new process is the manufacture of tert-butyl alcohol by a one step hydration of isobutene in mixed butenes, using the heteropoly acid

H3PMo12O40 as the catalyst (61)

Microbial enzymes are suggested as important future catalysts, but the only commercial process developed so far is for acrylamide (61). Recently (53) biocatalysis has produced commercial qualities of muconic acid for $3-5 $/lb vers $30/gram in lab quantities by chemical synthesis.

The demand for higher product yields, waste minimization, and environmentally safe raw materials and intermediates (53) is prompting research to develop new routes to old chemicals, but catalyst research and development is not keeping pace with the needs of industrial production, environmental protection, and social demands (61).

It is expected that customer linked commercialization is the key change in catalysts in the 90s (58)

There is a need for new catalysts for emissions from lean-burn gasoline engines, for odor control of living space,for catalyst that can withstand sulfur in refinery operations, for catalysts for intense hydrocracking, for catalysts that can be regenerated, for oxidizing SO2 to SO3 at lower temperatures (and more favorable thermodynamic equilibrium) that in use today, for reducing NOx to N2 in cars exhaust, for the direct oxidation of benzene to phenol, for coupling acetic acid and ethane to make vinyl acetate (61).

Catalysts have been developed in Israel at universities, by Israel Chemicals, and by Makhteshim, but only the latter has used Israeli developed catalysts. The largest quantitative demand for a catalyst is for FCC cracking catalysts by the refineries.

A catalyst manufacturer in Israel should start by producing conventional catalysts, such as cracking or oxidation catalysts for the local market, and continue with a few new proprietary catalysts after tests of their use by prospective clients. Quality assurance and close contact with customers are prerequisites for this business.

7.2.3 Food additives

Food additives suffer less than other specialties from cycles in demand, but are more sensitive to government regulations, and require Good Manufacturing Practice in order to market them world wide.

Tables 40-42 show the food additives markets in the U.S. by category, by specific chemicals and by targets.

Table 40

Sales of food additives in the U.S. in 1990 (117,118)

Category	1990	1995 forecast	Projected growth
	$MM	$MM	%
Sweeteners	1000	1310	5.5
Thickeners	884	1100	4.5
Flavors/enhancers	600	785	5.5
Emulsifiers	460	515	2.3
Acidulants	246	287	3.1
Colors	220	272	4.3
Vitamins/nutrients	157	177	2.4
Enzymes	143	169	3.4
Preservatives	83	92	2.1
Other	500	585	3.2
Total	**4317**	**5319**	**4.3**

The worldwide market for fragrances in 1993 was estimated at $4 billions and at $5 billions for flavors. The growth rate is estimated at 3-5% for fragrances and slightly higher for flavors (65).

Table 41

Sales of specific food additives in the U.S. in 1990 (117,118).

Product	Sales $MM	Function
Aspartame	750	Sweetener
Vanillin	160	Flavoring
Citric acid	160	Acidulant
Monosodium glutamate	75	Enhancer
Xanthan gum	50	Thickener
Sorbates	55	Preservative
Carrageenan	45	Thickener
Caramel	40	Colorant
Total	**1335**	

Table 42:

Sales of food additives by market in the U.S. in 1989 (117,118).

Food additives market	Sales 1989 $MM	Projected sales 1994 $MM	Change 89 - 94 %
Soft drinks	728	1170	10.0
Sauces, dressings	432	675	9.3
Meat, seafood	330	455	6.6
Dairy products	285	415	7.8
Baked goods	273	395	7.7
Frozen foods	148	220	8.3
Grain mill products	108	150	6.8
Alcoholic drinks	53	70	5.7
Other	206	350	11.2
Total	**2563**	**3900**	**8.8**

Significantly most food additives are projected to have a high growth rate, soft drinks are the largest target market for food additives, and sweeteners, particularly aspartame have the greatest sales.

The Israeli chemical industry has long been active in the food additives market, from natural raw materials and by synthesis. It has the potential to increase greatly its activity in this field.

7.2.4 Advanced ceramics

The world production of ceramics in 1991 is estimated at $15.3 billions, of which the US and Japan each account for about a quarter (21)

The more pedestrian uses of engineering ceramics grew from $350 million in 1975 (1983 dollars) to more than $1 billion in 1983 in the US (23).

The world market for advanced materials was estimated in 1986 (24) to include $5.1 billions for ceramics.

The advanced ceramic structural ceramics market in the U.S. was estimated in 1987 at $171 millions, and was expected to grow to $1.16 billion in 1995 and $2.6 billion in 2000 (22). The specific markets in order of size are: Automotive/heat engines, wear parts, Aerospace, Cutting tools, bearings, heat exchangers and bioceramics (21).

New advanced structural ceramics, ceramic coatings, electronic ceramics provide high performance under extreme mechanical, electrical or environmental conditions (24):

The demand for new materials follows closely the advance of technologies in areas such as machinery, plant equipment, transportation, and aerospace (19).

The development of new materials and technologies such as amorphous metals, metallic alloys, diamond films, photovoltaics, rechargeable batteries, high temperature superconductors, and metal and plastic composites will continue to grow, despite the cutbacks in military spending (19).

The most common monolithic advanced structural ceramics are alumina, silicon carbide, silicon nitride and zirconia. Ceramic composites contain fibers that are added to the monolithic ceramics in order to improve toughness. Advanced structural ceramics are currently used for wear parts, cutting tools, bearings, heat exchangers, aerospace applications (21)

The added value in advanced ceramics is high. The main requirement for success in this field are innovation, and understanding the market needs.

Israel is already a leader in high quality periclase, and has considerable research activity in advanced ceramics. The Israeli chemical industry can and should increase its activity in this field.

7.2.5 Advanced polymers

The world market for advanced materials was estimated in 1986 to include $1.2 billion for polymers (24).

The demand for new materials follows closely the advance of technologies and encourages the trend for lighter weight plastic composites (19).

The market growth rate of high performance thermoplastics have slowed due to the decrease in military spending. Civilian customers are not willing to pay as much for slightly improved properties. In order to succeed in this still fast growing market it is necessary to develop low cost production methods of the monomers, and have a critical mass of a portfolio of high performance polymers in order to serve a high variety of customer needs (20). These products include: Liquid crystal polymers (LPCs), Polyamide-imides (PAI), Polyarylates, Polybenzimidazole, Polyetherimide (PEI), Polyethersulfone (PES), Polyimide(PI), Polyketones, Polyphenyl ether (PPE), Polyphenylene sulfide (PPS), Polyphenyl sulfone, Polyphthalamide (PPA), Polysulphone (PS).

The Israeli chemical industry manufactures mainly basic polymers, such as polyethylene, polypropylene, polystyrene, some polyesters and nylon, but has not, so far, gotten into the advanced polymers field. Some research in this field is done at universities. Entrance into this market requires advances in chemistry and understanding the markets, but the return is likely to be high.

7.2.6 Composites

The world market for advanced composites was estimated in 1986 to be $1.7 billion (24). The worldwide composite use in 1990 is shown in table 43.

Table 43

The worldwide composite use in 1990.

Market	\$MMM
Aircraft/aerospace	2.3
Industrial	1.0
Recreational	0.6
Total	**3.9**

The growth rate for the 90s was projected at 10%. The forecast for the total composites market was for \$MMM 5.5 in 1995, and \$MMM 8.5 for 2000.

Another forecast by the U.S. Department of Commerce (121) projected the total advanced materials at \$MMM 400 billion for 2000, without specifying what fraction will be for composites.

The demand for new materials follows closely the advance of technologies in areas such as machinery, plant equipment, transportation, and aerospace. Demand for new materials and technologies is generated by trends that encourage energy conservation and efficiency, more powerful personal computers and workstations with increased portability, higher performing and lighter weight metals, ceramics and plastic composites (19).

New advanced materials that provide high performance under extreme mechanical, electrical or environmental conditions (24) include advanced polymer composites. One definition of polymer composites is: Polymer composites consist of high-strength or high modulus fibers embedded in and bonded to a continuous polymer matrix. Analogous definitions may be made for ceramic and metal composites, and their combinations. The fibers may have a variety of dimensions, geometric arrangements, and continuity, and the matrix may give a verity of mechanical, chemical, optical, electrical etc. properties. The total number of combinations is large, and the complexity of the resultant structures is high (121,122).

The macroscopic arrangements of these materials depend on the microscopic structures and requires consistent methods of preparation. Nanocomposites consist of very small particles of a guest material (nanoclusters having a diameter less than

100 nm) in a host matrix. Their photonic activity may make them suitable for optical computers.(124).

A clear trend in composites is towards a microstructure, in which the reinforcement is not necessarily composed of fibers. Composite structures may enter the molecules. Dendrimers are layered spherical molecules. They are able to change polymer properties and may allow processors to injection-mold plastics, previously limited to thermoforming (123).

In Israel the fiberglass reinforced unsaturated polyesters have been manufactured since the 60s, and polyester resins were produced here for this purpose. The local fiberglass production was only of insulation and not of composite quality. There was no production of more advanced resins, such as epoxy or polyimides. There is no production outside of the armament industry of advanced composites, but some research has been going on for a long time at universities. there is potential here for entry into this field that will develop into a major field in the future.

7.2.7 Drugs

Analyst Enrico T. Polastro of ADL Brussels estimates the value of worldwide chemicals used as drugs at $MMM 15-17 billions (40).

Within the drug market, dollar sales for single enantiomers of chiral drugs are likely to grow at the expense of racemates. In the coming age of managed health care, the big winners will be companies that make chiral drugs and seven days adhesive plastic film patches formulated with single isomers of chiral drugs (126).

The world sales of chiral drugs were estimated at $MMM 35.6 (Table 44), a growth of 22% over 1992, and is expected to grow to over $MMM 40 in 1997.

Table 44

World sales of enantiopure drugs in 1993 (126).

Type	Sales $MMM
Cardiovascular	11.3
Antibiotics	10.8
Hormones	4.5
Central nervous system	2.0
Anti inflammatory	1.5
Anticancer	1.0
Other	4.5
Total	**35.6**

There is also a potential for chiral compounds in the food, feed additives and fragrances markets.

A variety of new syntheses of stereospecific compounds have been developed (13,14,126). This field is young and there is lots of room for innovations.

The difference of price for the same chemical between its manufactured cost as a chemical, and its cost as a packaged drug is a factor of 10 to 100.

The Israeli drug industry (Mainly Teva and Taro) has been successful in getting early to the market with generic drugs, and has been not been as successful in the introduction of new drugs. The entry fee for a new drug is too expensive for the Israeli industry, and is best achieved in a partnership with one of the large world companies. The entrance fee for an enantiopure isomer of an existing drug is likely to be cheaper and within the reach of the Israeli chemical industry.

7.2.8 Detergents

The major components of detergents are not the surfactants but the builders. The most cost effective builders are polyphosphates (generally STPP), but their use is being phased out, since they encourage growth of algae and plant growth when they end up in streams and lakes. The common substitutes are zeolites for powdered detergents and citrates. Other substitutes are: carbonate and soluble silicates with polyacrylate dispersants used for liquid detergents. The 1993 world production of STPP is around 2.5 million tons (of which about 420,000 tons in the US). The production of anhydrous zeolites in the US for builder use was about 300,000 tons in 1993 (48).

None of the STPP substitute is even close in cost effectiveness to STPP.

The new popular formulation of detergents is based on alcohol sulfates, and a more efficient zeolite builder that does not require a polycarboxylic acid as a co-builder (49).

Unilever uses a family of organomanganse complexes that catalyze hydrogen peroxide bleaching at about 20 C. These catalysts can be used at low concentrations, as low as 0.1% of the detergent formulation. One of these catalysts, known as Accelerator, is an ingredient of a controversial new detergent formulation, called Persil Power in the UK and Omo Power in the Nederlands. Rival manufacturer Proctor & Gamble charges that the product damages clothes. Unilever has, at least temporarily, modified its formulation (49,50).

If Unilever overcomes the machinations of its rivals, it will revolutionize the detergent industry, since it will make it possible to get good cleaning and bleaching action at low temperatures, and will increase the market for the peroxides that are used in detergent formulations.

In Israel, most of the detergent formulations still use the classic linear sulfonates and polyphosphates. The entry of imported detergents into the Israeli market has so far not awakened the detergent producers to the competition.

The state of flux of the world detergent industry is a good opportunity for new innovated components and formulations to be developed by the Israeli chemical industry.

8. Technologies, systems and services

8.1 Introduction

The boundaries between specialties and chemical technologies are not sharp. However, we have bundled in this chapter, a number of technologies, that in general involve more than one defined market.

Some of these technologies, such as membranes, or superconductors are technologies per se. Some such as ozone or cyanides involve special chemistry.

A few of these technologies are not new, but were chosen because they show great promise today.

A few technologies (cyanides, or phosgene based) may be inherently dangerous, or require special equipment, but usable with the proper know-how. All these technologies demand innovation, special technical expertise and familiarity with their markets.

8.2 Promising technologies

8.2.1 Environment Control

The world environment control industry is estimated at $270 billions in 1991 (27), $300 billion in 1994 (26), and is expected to grow to $399 billions by 1996. Solid waste management is the largest industrial segment and the most mature. Resource recovery and recycling is the second largest industrial segment.

Other estimates of the world market of the environmental control industry are $200 billions in 1990, and $300 billions in 2000 (28).

It is very attractive to the chemical industry that had been a major pollutant, and is spending large sums to control pollution and to abate old pollution sites, to be in the business of controlling pollution of any type from any source. The potential market is large and will grow. The technologies are still under development, and it is a proper time for the Israeli chemical industry to utilize its experience and innovation skills and get into this business.

8.2.2 Controlled release

The main thrust of controlled release is for medical purposes. However, there is a growing market for controlled release fertilizers.

The wholesale value of the US controlled release fertilizer was estimated to be $175 millions in 1990. The farm use is for strawberry, citrus, vegetable and melon producers. The cost varies from $250/ton for sulfur coated urea to $1200/ton for polymer coated fertilizers. (compared with $146/ton for non coated urea). Erratic release rates result in plant damage, and product liability risks are considerable (39).

Much research has been conducted in Israel in this field, and there have been a few implementations for medical purposes. The Israeli chemical industry, that is strong in the fertilizer market, should also get into more sophisticated controlled release fertilizers.

8.2.3 Superconductors

The global market for high and low temperature superconductors is expected to rise from $1.5 billions in 1992 to $150 billions by 2020 (29).

Another superconductor world market forecast is (28): $MMM 1.5 in 1993, $MMM 8-12 in 2000, $MMM 60-90 in 2010 and $MMM150-200 in 2020.

Chemical compounds supplied to the electronic field are subject to rapid change and market fluctuations, more so than in other industry. They require close cooperation with the electronic industry (30).

Even if the above optimistic market estimates are not achieved, superconductors are going to be an important technology. Much research, some of which is applied research is undertaken in the universities in Israel. The Israeli chemical industry, should get involved.

8.2.4 Membranes

World sales of membrane filters and elements were expected to top $2 billion in 1991 (51). Assymetric membranes for the separation of nitrogen from air are expected to rise fast.

Main uses of membrane technology are (52):

Large scale membrane gas separators are used for hydrogen recovery in petroleum refineries, and for production of carbon dioxide for enhanced oil recovery, and in methanol production and for reverse osmosis and nanofiltration.

Small scale applications are for the preservation of food during
transportation by nitrogen blanketing, for the generation of inert gases for safety purposes, and for the dehydration of gases.

For oxygen-nitrogen separation, the membranes of choice are usually from polypyrrolone, polytriazole and polyaniline.

A new promising membrane is a nanoporous carbon membrane that is particularly effective for separating hydrocarbons from hydrogen in low pressure gas streams.

Future membranes include membranes with high selectivity for a given pair of gases, novel new composite membranes, and the ability to alter membrane characteristics after manufacture in order to increase their adaptability.

Some new uses for membranes are: the recovery of chlorinated hydrocarbons (98), the dewatering of azeotropic mixtures by pervaporation (99), and the recovery of VOC from gas streams (100).

In Israel membranes are used for reverse osmosis, and for the electro-chemical production of chlorine and caustic.

Nanofiltration membranes made by a local producer (97) are mostly exported.

The potential of this technology is obvious, and should be targeted by the Israeli chemical industry.

8.2.5 Biotechnology

Biotechnology, the golden promise of the past decade has drawn a great amount of risk funds, and has generated meager profits and great losses.

There are 1050-1100 specialist biotechnology companies worldwide, and another 625-725 with an interest in biotechnology. 12 companies had at least one year profit. There are two companies with overall profitability. World sales of biochemicals equipment and consumables are around \$2.0-2.5 billions. World sales of biochemicals have been estimated at \$5.9 in 1992. The biotechnology sector employs 70,000-80,000 people. Biotechnology R&D expenditure is estimated as \$4.9 billions in 1992 (about the same as the combined R&D of Bayer, Hoechst and Ciba). The current values of sales of biotechnology products in the agriculture market is about \$184.5 millions (36).

In the U.S. the total number of genetically engineered drugs receiving approval by the US FDA in 1982 to 1992 was 17, (3 in 1992). The approved drugs have enjoyed extremely lucrative sales. However, only 3 of the 24 largest biotechnology firms in the US have reported profits in 1992. Agricultural genetically engineering products have had small sales volumes and no profits in 1992 (31). Four of the larger 26 biotechnology companies in the U.S. showed profit in 1993 and three new products received FDA approval (32). Only four of the 20 larger U.S.Biotechnology companies showed profit in the first half of 1994 (33).

The most active area, where more profits were anticipated was in drugs and diagnostics. There were more successes in diagnostics than in drugs.

The less exotic plant genetics area is more promising. Genetically engineering of plants to accept genes from certain bacteria in order that the plants may protect themselves against certain insects, which reduces the need for chemical insecticides. Bio-pesticides of interest are non toxic, biodegradable and are effective in killing insect in their immature stage (34). Efforts are underway to create plants that produce their own pesticides, that are more resistant to herbicides and to frost, disease and drought, that contain more starch or a different mix of proteins (35).

The classic biotechnology that has long been part of the chemical and food industries is fermentation. Of the about 200 commercial fermentation products only three (ethanol, mono sodium glutamate and citric acid) can be considered as commodities. Other commodities produced by fermentation in the past, such as glycerol, acetone and butanol, are no longer produced by fermentation. However, antibiotics lead in the value of the products, and the new genetically engineered products lead in unit prices (64). The main changes in this industry are that more antibiotics are produced, and a few genetically engineered RDNA proteins have reached the market. The current research trend is for high value genetically engineered products and not to bulk chemicals (64). Indeed, the past expectations that biotechnology will change the face of the chemical industry have disappeared.

In Israel, there is much academic research and some applied research in all areas of biotechnology. Many small companies were formed, and a few, that have developed new diagnostic tools are expected to grow. The one biotechnological company that was one of the first companies in the world to develop marketable drugs, was taken over by a U.S. company, and stripped of its knowhow.

Genetic engineering of plants and medical sensors are recommended to the Israeli chemical industry. These areas least likely to lead to catastrophic failures, and are assured of good world markets.

8.2.6 Custom manufacture

Large companies do not want to mess around with pesky little chemicals, even when there are market quantities involved, and find an advantage in contracting out the chemical manufacturing, commonly supplying the raw materials and taking the product (62). Smaller companies are more flexible, and have faster start ups. Much of the contracting out crosses borders, since when expensive chemicals are involved, the shipping costs are not a factor.

Consortia of fine chemical firms in the UK, Eastern Europe and former USSR are focusing on obtaining custom processing projects by US firms, particularly in the drug industry. This is particularly useful in cases of in house manufacturing inefficiencies (63). The cost of R&D a new drug is about the same as for a me-too product, which will have greater competition in the market.

One estimate of the worldwide value of custom chemical production is $M12.5 billions. About 600 producers (400 in the US) employ about 45,000 people. Other estimates put the market in the range of $26-34 billions (63).

Israeli chemical companies can, now that the Arab boycott was practically lifted to get into this market.

8.2.7 Ozone

Ozone is expensive, relative to oxygen, as an oxidation agent, but is more powerful, and can lead to products that are more difficult to obtain by conventional oxidation.

As an example of the use of ozone is the generation of an exclusive range of products by the technology developed by Chemie Linz. It is based on the oxidation of a double bond by ozone, with subsequent reduction. This leads to an aldehyde, which may then be converted to acid or alcohol. The versatility of this reaction is remarkable.

The compounds produced by this method in commercial quantities are:
o-Phthalaldehyde
dimethoxytetrafydrofurane
Pyruvic acid methyl ester
Succinic dialdehyde
Phthalazine
Pyruvic acid ethyl ester

All these compounds have commercial applications and ton lots are available.

This was an example of what strength in a particular chemistry can achieve. However, the potential for other interesting oxygenates is good, and should be viewed as such by the Israeli chemical industry.

8.2.8 Halogenation

Israel is a leader in bromine compounds, and Chlorination was discussed in Chapter 2. A field in which Israeli companies have not been active much is fluorides, except for some research on the recovery of HF from the phosphoric acid plants.

The more interesting market for fluoride technology is for non ozone depleting refrigerants, electronic cleaning solutions and fire fighting compounds (Halons).

The development of these new compounds was driven by a rush to replace the old CFCs by HFCs, without too much consideration for the customers.

For instance (25), Allied Signal has started full scale production of its non-ozone-depleting refrigerant, Genetron AZ-50. It is a patented proprietary azeotropic mixture of HFC-125+HFC-143a, and has been endorsed by refrigeration system makers, compressor manufacturers and valve manufacturers. It is expected to replace R-502 and HCFC-22 in low and medium temperature commercial refrigeration equipment. DuPont's bid for the R-502 market, Suva HP 62 is an non azeotropic blend of HFC-125, 143a and 134a. These new refrigerants require replacements of seals, redesign of compressors, heat exchangers and valves, that make manufacturers of this equipment happy, and leave the customers frustrated.

There is an opportunity for anyone who develops HFC combinations (probably azeotropic mixtures of more than 2 components) that will match closely the properties of existing refrigerants, to obtain a significant advantage over the large companies which have committed large development and construction capital to less favorable compounds.

8.2.9 Cyanide chemistry

The commercial use of cyanides requires careful handling, and considerable safety consciousness. Hydrogen cyanide is a by-product in the production of acrylonitrile, a wide-spread intermediate, and is used as a reagent by many companies.

As an example of what can be manufactured with hydrogen cyanide is the range of chemicals produced by Hampshire Chemical Corporation, formerly a division of W.R. Grace:

Synthetic amino acids
Nitriles
Amino nitriles
Cyanohydrins
a-Hydroxy acids
Hydantoins

This is another example of what good chemistry plus the technology of handling a dangerous compounds may accomplish.

8.2.10 Supercritical technology

The first commercial uses of the supercritical fluids were in the field of extraction, mainly in the food industry (96). However, supercritical extraction is unlikely to replace ordinary extraction. The advantage of supercritical extraction is the easy separation of the solvent and the low quantities of solvent left in the product, and hence its applications in the food industry.

Recently, promising additional techniques emerged:

Supercritical medium for polymerization.

Supercritical water oxidation replacing incineration (125).

Supercritical reactions such as the supercritical CO_2 route to formic acid or the biocatalysis of polyesters in supercritical fluids.

These applications require special equipment and special skills which

9. Recommendations

9.1 General strategy

As stated in chapter 5, The key terms in all the strategies for success are: innovation, internationalization, efficiency, service, and open minds.

Innovations shift competitive advantages, by developing new technologies, anticipating new or shifted buyer needs, perceiving the emergence of a new industrial segment, using a shift in input costs, or raw materials, energy or transportation availability, and adjusting to new government regulations (69).

Internationalization of the chemical industry is inevitable. The Israeli chemical industry has a number of production facilities and part ownerships abroad, and a few Israeli companies are owned by non Israeli groups. This trend in both directions should be encouraged, when a specific case has an economic or market advantage.

Efficiency requires professionalism of all employees and managers, which in turn require good training facilities.

Service requires good understanding of the markets, and some presence near the clients. However, when a good information highway is developed, some of this presence may be virtual.

Open minds of the leaders of the industry requires a special rare breed of persons that should be selected and developed.

9.2 Specific areas

9.2.1 Adding value to current products

Much of the growth in production and exports of the Israeli chemical industry has been in large quantities, low value, beneficiated raw materials, such as phosphates and potash, and first layer chemicals, such as technical phosphoric acid, fertilizers, distillates and petrochemicals.

The growth of the chemical industry should be directed to higher value chemicals based on the few available raw materials from the Dead Sea, the phosphates field and the small petrochemical industry, and on imported intermediates. This has been the strategy of a few Israeli chemical companies.

Integration downstream, as close as possible to the final customer, has the prospects of highest returns and should be pursued.

9.2.2 Joint ventures and new foreign markets

Joint ventures are becoming very common in the chemical industry, where each partner brings some of the required elements for the venture: Capital, knowhow, skilled designers, experienced operators, environment and market savvy. In the case of a joint venture in another country the local company brings its familiarity with local laws, bribery, getting approvals, subsidies and guarantees.

In tripartite joint ventures, the inputs come from three companies, usually from three different countries, and again, the capital, design, knowhow, and skilled people comes mostly from the non local companies.

Israeli chemical companies can be partners in bipartite or tripartite joint ventures, and can supply knowhow, initial management skills, engineering, training and some of the capital. In the case of implementation in Israel, they can supply all the above mentioned local inputs.

For Eastern block countries, Israel has large numbers of people who speak the local languages, which can expedite communications when a plant is constructed.

9.2.3 Special niches and opportunities.

The Israeli chemical industry has carved for itself a small number of special niches: Potassium nitrate, clean phosphoric acids, bromides, and high quality periclase. Each success carries with it the risk of competition, and of the loss of the dominant position in the niche, if we do not continue to improve the product and give good service to the customers.

The Israeli chemical industry can enter existing niches of specialty chemicals and technology, dominated currently by other countries, if it aggressively pursues R&D in these areas.

Examples of special opportunities that had been pursued by the Israeli chemical industry are the export of distillates by the refineries in the years when the dominant local market was for heavy fuel oil, the use of grain shipping to Israel to carry bulk fertilizers on the return trip,and the use of bulk liquid import ships to export the products of the starting petrochemical industry.

Chemical companies should always be on the look for similar special opportunities.

9.3 National policy and organizations

9.3.1 Introduction

The national goals are not always in line with the goals of an industry. For instance, an important national goal is high employment rate, but an equally important goal of industry is to obtain higher productivity. Both goals will coincide, only if the increased production rate is high.

It is up the government to see that its and industry's goals coincide. In the past the government saw to that by owning most of the chemical industry. Those times have gone, and the government will finish selling off its share in the chemical industry in a few years.

The tendency in Israel used to be government control of every aspect of the economy. This, too, is changing. Here, again, the government can direct industry to national goals by inducements and encouragements and not by rules and controls.

Such inducements should serve national goals of increasing production, exports and jobs. It has been easy to abuse government inducements by unscrupulous people, who used government grants and subsidies to line their own pockets and disappeared, or in rare cases landed in prison.

In no case should the government support a project that will be uneconomical without massive government subsidies. Such projects, such as the Lavie project, or the idealistic sea to sea channel, usually end in uncontrollable losses.

In its eagerness to attract investment the government had the Knesset approve laws that were used for the benefit of single companies, although on occasion other companies found loopholes and took advantage of these laws.

Occasionally a minister decided to give extra large inducement to one company which caused a rush of other companies to request the same benefits.

A few specific recommendations follow:

9.3.2 Indirect support

The direct grants and loans to companies should be eliminated gradually.

Instead, the government should support industry indirectly by financing the infrastructure: good roads, railroad lines, communication lines, and services (Water, sewage, electricity) connections to industrial sections.

An emerging important service is the proliferation of databases for every field of endeavor. This service should also be considered as part of the infrastructure to be supported by the government, in order to make available all important technical, patent, and business databases at a reasonable cost to industry, by networking from a central up-to-date and continuously updated repository.

Another important indirect support is for training skilled people at all levels. This can be achieved by government subsidies of good technical schools and technical higher studies, or of students in such schools, that take up a career in industry.

A new popular business in Israel is training courses. An employee receives a special raise every few years if he takes a prescribed number of hours of study of subjects, useful for his/her career. This objective is often abused, by low level courses, and 3 hour sessions that count as 8 hours of study. Industry, that eventually pays the employees, should be involved in seeing that the employee gets real professional benefits from such studies.

Similarly abused is the professional development fund (2.5% of the salary by the employee and up to 7.5% by the employer). A fraction of that sum goes to the union that uses it indiscriminately. An employee in many cases can take a vacation abroad under the guise of technical visits. These funds should be used for the original purpose of professional training.

9.3.3 Direct support

Important direct support employed in many countries, including by Israel, are tax inducements, such as accelerated depreciation and/or income tax in the first years of operation. Such inducements have proved their usefulness for the success of new projects.

Another important direct support is for R&D. It can be in the form of recognition as expenses of R&D supported or run by the company at research institutes or at universities. In Israel, the government supports R&D in established and in young companies by covering part or all of the R&D costs of specific projects. If the project is successful, the company is supposed to pay the government a royalty, and in rare cases, the government receives back its investment in the company R&D. The natural result is an inducement for the companies to request support for the high risk projects and not for the sure things.

This loophole can be closed, if the companies are required to pay the government back a fraction, say 50%, of the government support of unsuccessful projects. This will lead to early elimination of worthless projects, and for developing a growing fund for support of deserving projects.

9.4 Manpower requirements

The key to a successful industry is professionalism at all levels; i.e. highly trained people who know how to perform their jobs well, wish to perform well, and are proud of their contributions to the production. Unlike employees with the only qualifications of belonging to the right party, or having good connections, or as "deserving" persons.

Quantitative assessment of the manpower requirements of the chemical industry are not necessary. The chemical industry is capital and not labor intensive.

In the past, when technical manpower was scarce the industry solved the need by hiring unemployed seamen, with technical experience or by setting up their own technical schools. When chemical engineers were scarce, mechanical engineers were hired and trained on the job. When there was a surplus of chemical engineers some of them were employed as shift foremen. In short, the industry can fill its manpower needs by inducements, training and retraining, and has no need of external support, except for the above recommendations in section 9.3.2.

Appendix I

Summary of the recommendations of the US National Academy of Engineering (7).

The competitive environment for US based companies is being recast by a number of powerful trends:

1. The technical intensity of most manufacturing and service industries will continue to grow at an accelerating pace, and commercial technology will become increasingly science-based and interdisciplinary.

2. National security claims on the US technical base will continue to diminish, and national defense capability will become increasingly dependent on technologies developed and applied first in the commercial sphere.

3. The current revolution in production systems will continue to transform product and service companies and bring a new level of attention to the optimal use of human talents in the workplace.

4. International competition will continue to intensify as world industrial and technological capability becomes increasingly distributed among industrialized nations.

5. Local and regional clusters of industrial activity - and their associated human, material and institutional capabilities - will continue to play a major role in national economic performance and exert a counterprevailing force to rapid internationalization.

6. Internationalization of economic and technological activity will, however, continue, deepening the interdependence of national economies and blurring the distinction between the domestic and foreign policies of nations.

These trends reveal weaknesses in the US technology enterprise that compromise the nation's ability to develop, acquire, and use technology to economic advantage. The most important of these weaknesses are:

1. Outmoded public and private sector management philosophies, organizational frameworks, and human resource strategies.

2. Insufficient investment in, and poor quality of, US workforce training and continued education, particularly at the non supervisory level.

3. Inadequate investment by US based companies in competitive production processes, plant and equipment.

4. Low civilian R&D intensity of US economic activity and insufficient breadth of the nation's civilian R&D portfolio, including underinvestment in growth and productivity enhancing technologies that are high-risk or whose benefits are difficult for individual investors to appropriate.

5. Insufficient awareness of, and interest in, technology originating outside their institutional boundaries on the part of many US companies and federal laboratories.

6. Lack of a strong institutional structure for federal technology policy in support of economic development and the segregation of technological policy from domestic and foreign economic policy at the federal level.

Goals and policy recommendations:

Goals:

A. Foster the timely adoption and effective use of commercially valuable technology throughout the US economy.

B. Increase civilian R&D investment in the US economy and close emerging gaps in the nation's civilian technology portfolio.

C. Access and exploit foreign technology and high-tech markets more effectively to advance the interests of US citizens.

D. Create a strong institutional framework for federal technology policy in support of national economic development, and integrate the planning and implementation of federal technology policy with that of national domestic and foreign economic policy.

Specific recommendations (The letter following the recommendation number is the specific goal number:

1(A). Catalyze the development of a dense national network of public and private providers of industrial modernization services that is capable of meeting the diverse needs, including training, of 20-25 percent of the nation's small and medium sized manufacturing companies by the year 2000. Expand the National Institute of Standards and technology's Manufacturing Technology Centers programs and State Technology Extension Program as a first step towards this objective.

2(A). Support experimentation with a wide range of public and private initiatives at the federal, state and local levels to increase the quantity and improve the quality of school-to-work transition programs and of job related training and continuing education for the nation's nonsupervisory work force.

3(a). Establish a high prestige national fellowship program, to be administered by the

National Science Foundation, for advanced study of the technical and organizational aspects of manufacturing. Structure then program not only for university graduate students and faculty but also for practitioners from industry.

4(B). Replace the incremental Research and Experimentation (R&E) Tax Credit with a permanent tax credit on the total annual R&D expenditures of a company. Extend the R&E tax credit to cover industry sponsored R&D in universities and other institutions, and the industrial contribution to R&D performed as part of a consortium that involves government laboratories.

5(B). Use public procurement, tax credits, accelerated depreciation schedules, regulation, and other demand oriented policy instruments to pull innovation and increased private sector investments in technologies expected to yield particularly high returns to US society as a whole. These include technologies that produce environmentally benign and energy efficient products and services and technologies that reduce the cost of health care delivery.

6(B). Experiment aggressively with options for direct federal support of the development and diffusion of a broad portfolio of commercially relevant or promising "infrastructural" and "pathbreaking" technologies. rely on industry leadership and involvement in project initiation and design, and on significant private sector cost sharing to ensure commercial relevance. Options include expansion of the Advanced Technology Program and the Small Business Innovation research program, support of additional private sector managed industrial consortia like SEMATECH, creation of an independent federal Civilian Technology Corporation, and expansion of the measurement, standards, and testing activities of the National Institute of standards and technology.

7(C). Stimulate the expansion and institutionalization of US public and private sector capabilities for global technological scanning and benchmarking. Most of these activities should be carried out by industry associations or industrial consortia with some sharing of costs and planning responsibility with federal government agencies.

8(C). Develop a capacity within the federal government for seeding and stimulating international R&D consortia (private sector, public sector, or mixed) in areas of recognized foreign technological strength where gains to US participants are expected to be substantial. This is an important subset of the options for direct federal support of commercially promising "infrastructure" and "pathbreaking" technologies recommended above.

9(C). Improve coordination and cooperation between federal agencies with lead responsibility for science and technology policy by (1) rotating high-quality midlevel staff between these agencies, (2) establishing a technology and trade committee of the federal Coordinating Council for Science, Engineering, and Technology, and (3) making the integration of technology policy with domestic and foreign economic policy an explicit objective of the newly created National economic Council.

10(D). Establish an institutional focus within the federal government to monitor, harness, and supplement the many existing federal programs and capabilities that currently support or could support, more effective development, use, and diffusion of technology throughout the US economy. This institutional focus should work for the early incorporation of technological considerations into the formulation and implementation of US economic policy.

Appendix II

Summary of the ACS Interactive Presidential Colloquium: Shaping the future, The Chemical research Environment in the Next Century (12).

The main recommendations were:

1. Government, industry and university researchers should identify and enhance complementary areas of research to create synergy, to increase the overall productivity and effectiveness of the research enterprise, and to avoid competition for increasingly scarce research support.

2. Mechanisms must be enhanced to achieve personnel exchange among the academic, industrial and government sectors. Transfers, temporary and permanent, between sectors should become the norm.

3. Agreements and contracts defining the terms of alliances must be simplified, streamlined and, to the extent possible, standardized. A timeeffective process must be developed to arrive at mutually beneficial agreements for the allocation and utilization of intellectual property resulting from the alliances. The feasibility of umbrella agreements between all government agencies and the other sectors should be examined so that specific agreements can be readily negotiated within the established context.

4. A process must be developed and responsible parties assigned to identify the new products and processes resulting from alliances. The process should include the means to communicate these results to the chemical community, the larger public and the decision makers.

5. A forum should be created to address and resolve issues that may result from alliance activities. Mechanisms should be established to ensure communication of forum issues and their incorporation in subsequent agreements.

6. Graduate programs (in Chemistry) must provide a broader exposure to chemistry and appropriate related subjects, if necessary at the expense of some time in thesis research. More frequent use of the minor in graduate school should be considered, and students should be encouraged to attend courses and seminars outside their immediate specialties.

7. Federal funding agencies should grant more fellowships directly to students, providing some decoupling of financial support from the research process while maintaining the necessary core competencies in specific research areas important to the nation. With limited budgets this change could reduce direct funding of faculty, but should not alter the overall support of departments.

8. Government and industry should fund at a substantially increased level, separately or jointly, positions at universities and industry to facilitate personnel interchanges. Fellowships for senior scholars, internships, and co-op programs are possible mechanisms for such exchanges.

9. All colleges and universities, and especially those heavily involved in research, must rededicate themselves to providing the highest quality educational experience for all students. Chemical science and engineering faculty must be committed to offering outstanding educational opportunities to their students, on par with their commitment to the research and public service functions of higher education institutes.

10.Chemist and chemical engineers must adopt a sense of urgency in responding to the demands of the public and political leaders to refocus our scientific and technical effort on important national problems. It is not appropriate, nor will it be successful, for scientists to claim that their work has no direct relevance to practical ends or that it should not have such relevance.

11.The scientific establishment should recognize and appropriately reward the activities of individual scientists who convey a sense of both the wonder of science and its many contributions to the public welfare. Scientists who by virtue of major accomplishments, special opportunity, or unique gifts of effective communication achieve widespread public acclaim should be valued for their important work.

12.The chemical community must recognize the diverse audience to whom a strong case for the importance of the chemical sciences and technology to modern life must be made. Appropriate strategies and approaches are needed to reach these different segments of the public.

13.The American Chemical Society along with the scientific and engineering community, must redouble its efforts to communicate both the nature and substance of chemical sciences and technology to all sectors of the public, through such mechanisms as the print media, television programs, programs of individual outreach, and "hands-on" experiences such as museum installations. Although the print media are important to the overall success of such efforts, we must explore other avenues to communicate with the public, including computer technologies.

14.The universities working in conjunction with industry, need to determine the type and level of basic knowledge required to advance industrial goals and to establish a mechanism to channel research results to the appropriate parties as quickly and as effectively as possible. Similarly, the university community must help the federal agencies that fund basic research by identifying and specifying the relationship of their research to established national objectives wherever possible.

15.In order to preserve the health of the scientific base that supports the chemical and allied industries and to use that base to expand into new competencies, industry must recruit the best scientific and engineering staffs capable of utilizing the knowledge generated from any sector. In addition, industry must better communicate the value of basic research to its own management and stockholders.

16.The federal government must sustain investment in basic research by its mission-oriented agencies, and preserve the mandate of the National Science Foundation and the National Institute of General Medical Sciences to support fundamental research.

Additional recommendations deal with graduate programs in Chemistry, and the encouragement of minorities.

BIBLIOGRAPHY

1. McKeever, L.D., Embrace the challenge of new technology, CHEMTECH, September 1993, pp. 16-21.

2. Ainsworth, S.J., Issues management is central to Frank Popoff's globalization strategy, C&E News, May 23,1994, pp. 25-29.

3. Thayer, A., Chemical managers analyze restructuring, C&E News, May 16, 1994, p. 34.

4. Weber, J., Lean, mean and healthier, Chemical Week, January 10, 1994, p. 43.

5. Thayer A.M., Chemical companies see beneficial results from ISO 9000 registration, C&E News, Apr 25, 1994, pp. 10-26.

6. Office of Science and technology: National critical technologies, The White House, 1992.

7. National Academy of Engineering, Mastering a new role: Shaping technology policy for national economic performance, National Academy Press, Washington (1993).

8. Wagner, H.A., Planning for growth, CHEMTECH, July 1987, pp. 397-399.

9. Bennet, M.J., Boccone, A.A., Kline, C.H., The new chemical enterprise, CHEMTECH, March 1988, pp. 162-167.

10. Forney, R.C., Advanced materials and technological innovation, CHEMTECH, March 1988, pp. 178-183.

11. Lepkowski, W., National science policy: White House unveils long-awaited report, C&E News, Aug 8, 1994, pp. 6-7.

12. ACS Interactive Presidential Colloquium, Shaping the future, The chemical research environment in the next Century, CHEMTECH, August 1994, pp. 7-13.

13. Stinson S.C., Chiral drugs, C&E News, Sep 27, 1993, pp. 38-65.

14. Federsel, H., Drug chirality - scale-up, manufacturing, and control, CHEMTECH, December 1993, pp. 24-33.

15. Stinson, S.C., Global fine chemicals industry faces rising competition, squeeze on profits, C&E News, July 19, 1993, pp. 21-26.

16. Gerry R., R drugs invade the OTC market, Chemical Business, November 1992, pp. 8-10.

17. Shapiro, L., How analysts chart the pharmaceuticals, Chemical Business, April 1993, pp. 16-18.

18. Jones S., Pharma firms feel the heat, ECN Chemscope, March 1994, pp. 26-28.

19. Verbanic C., Advanced materials advance, Chemical Business, April 1992, pp. 11-13.

20. Reisch M.S., Advanced thermoplastics producers regroup, C&E News, August 30, 1993, pp. 24-37.

21. DeSapio, V., Advanced structural ceramics: Challenges to commercialization, CHEMTECH, November 1993, pp. 46-51.

22. Dagani, R., Ceramic composites emerging as advanced structural materials, C&E News, February 1, 1988, pp. 7-12.

23. Goodwin, D.A., Sagarese, A.A., Engineering ceramics: Where do they fit in?, CHEMTECH, March 1986, pp. 174-177.

24. Fasth, R., Eckert, C.H., Advanced materials markets, CHEMTECH, July 1988, pp. 408-412.

25. Hoechst Celanese raises acrylic acid, acrylate capacity 10%, C&E News, May 16, 1994, p. 28.

26. Gelbein, A.P., The phoenix rises again, CHEMTECH, July 1994, p. 1.

27. Anderson E.V., Slower growth, shift in emphasis expected for environmental business, C&E News, June 28, 1993, pp. 13-16.

28. Willis. L., The year in preview: 1994, CHEMTECH, February 1994, pp. 47-52.

29. Thayer, a., Superconductor device markets to flourish, C&E News, June 14, 1993, p. 29.

30. Oliver, J.O., The surge in electronic chemicals, Chemical Business, June 1992, pp. 9-12.

31. Thayer A., Poor 1992 earnings, shaky stocks plague biotechnology firms, C&E News, March 29, 1993, pp. 17-19.

32. Thayer A., Biotech industry makes progress despite difficult year in 1993, C&E News, April 4, 1994, pp. 15-17.

33. Thayer A., Biotechnology firms show mixed performance, C&E News, August 8, 1994, p. 27.

34. Dutton G., Biotechnology's coming of age, Chemical Business, May 1992, pp. 19-21.

35. Baum, R.M., Herbicide resistant crops: focus of biotechnology debate, C&E News, March 8, 1993, pp. 38-41.

36. Hodgson, J., Barlow, K., Facts and feats of the biotechnology business, CHEMTECH, December 1993, pp. 45-47.

37. Verbanic, C.J., Pesticides face a slowdown year, Chemical Business, March 1991, pp. 22-25.

38. Loesel A., What's special in specialties, Chemical Business, March 1993, pp. 6-8.

39. Schmidlkofer, R.M., The growing specialty fertilizer market, CHEMTECH, May 1994, pp. 54-57.

40. Stinson, S.C., Market, environmental pressures spur change in fine chemicals industry, C&E News, May 16, 1994, pp. 10-25.

41. Moore, T., The race is on for specialty chemicals, CPI Purchasing, July 1994, pp. 46-59.

42. Boer, F.P., the culture called specialty chemicals, CHEMTECH, February 1989, pp. 75-78.

43. Hamilton, W.G., Selling service chemicals, CHEMTECH, March 1987, pp. 150-151.

44. Williams, L.F., Specialized chemical companies, CHEMTECH, January 1981, pp. 22-28.

45. Daigle, S.R., Kline, S.A., Differentiate and add value, ECN Specialty Chemicals Supplement, May 1985, pp. 10-11.

46. Shamel, R.E., Strategies for the global chemical industry, Chem. Eng. Progress, August 1986, pp. 8-12.

47. Kline, C.H., Breaking through to new technologies, CHEMTECH, March 1984, pp. 148-151.

48. Ainsworth, S.J., Soaps and detergents, C&E News, January 24, 1994, pp. 34-59.

49. Layman, P., Unilever rolls out new generation detergent, C&E News, May 16, 1994, p. 35.

50. Freemantle, M., Chemistry of disputed detergent unveiled, C&E News, June 27, 1994, pp. 5-6.

51. Weiss, M., Membranes already top $2 billion, Chemical Business, September 1991, pp. 46-48.

52. Haggin, J., Membrane technology developments aim at variety of applications, C&E News, April 4, 1994, pp. 25-26.

53. Wett, T., The New catalyst Challenges, Chemical Business, January 1991, pp. 15-19.

54. Anon., Dow and Exxon jostle in race to bring metallocene products to market, Chemical Week, September 15, 1993, p. 5.

55. Stinson, C.S., Process catalysts continue on steady course, C&E News, February 17, 1986, pp. 27-50.

56. Hoffman, H.L., Catalyst market estimated, Hydro. Proc. February 1990, pp. 53-54.

57. Thayer, A.M., Catalyst suppliers face changing industry, C&E News, March 9, 1992, pp. 27-49.

58. Thayer, A.M., Catalyst industry stresses need for partners as key to future success, C&E News, July 11, 1994, pp. 19-20.

59. Catalysts for the process industries: Global business opportunities and commercial intelligence, Focus on catalysts, July 1994, p. 1.

60. Catalyst business is growing but consolidation still looms, Chem. Market Rep., May 23, 1994, p. 15.

61. Haggin, J., Concern grows over future course of industrial catalysis R&D, C&E News, July 25, 1994, pp. 25-30.

62. Schwartz, I., Custom chemical manufacturing: 1992 Report, Chemical Business, February 1992, pp. 16-26.

63. Stinson, S.C., Custom chemicals, C&E News, January 31, 1994, pp. 26-54.

64. Hinman, R.L., The changing face of the fermentation industry, CHEMTECH, June 1994, pp. 45-48.

65. Layman, P.L., Flavors and fragnaces business marked by growth, mergers, C&E News, May 30, 1994, pp. 10-11.

66. Landau, R. The chemical engineer and the CPI: Reading the future from the past, Chem. Eng. Progress, September 1989, pp. 25-39.

67. The MIT commission on Industrial productivity, The transformation of the US chemicals industry, part 2 of Vol 1 of the working papers of the MIT commission on industrial productivity, MIT Press 1988.

69. Porter, M. E., The competitive advantage of nations, Free Press, New York, 1990.

70. Plotzker S., You do not know how to market. An interview with Prof. M.E. Porter, Yediot, July 25, 1994.

71. Facts & Figures for the Chemical industry, C&E News, July 4, 1994, pp. 28-74.

72. Encyclopedia Britannica Book of the year 1993, pp. 792-796.

73. Methanol, in Kirk-Othmer's Encyclopedia of Chemical Technology, 3rd. ed., Vol. 15, pp. 403-414, Wiley, New York, 1981.

74. Methanol, Chemical Week, October 5, 1994, p. 48.

75. Methanol moves into a new era, Chemical Week, August 31, 1994, p. 36.

76. Hoechst Celanese methanol moves: Restart Clear Lake, sell AB shares, Chemical Week, September 21, 1994, p. 16.

77. Loebel J., Eliscu I., Derivatives of petrochemical block-products, Ministry of Industry report, 1979.

78. Derivative demand driving benzene, Chemical Week, September 28, 1994, p. 41.

79. Benzene, Chemical Week, August 17, 1994, p. 48.

80. Horowitz U., The techno-economic analysis of petrochemicals, Tahal Report, 1993.

81. Vinyl chloride monomers balancing act, Chemical Eng., August 1993, pp. 59-61.

82. Chlor-Alkali Market Report, Issue No. 3, August 25, 1994, p. 5.

83. Titanium dioxide producers whiten their ways, Chemical Eng., March 1994, pp. 69-71.

84. Vulcan Chemicals builds specialties portfolio around chlor-alkali core, C&E News, September 5, 1994, p. 12.

85. Catalysts, Chemical Week, October 4, 1994, pp. 25-29.

86. Ethylene, in Kirk-Othmer's Encyclopedia of Chemical Technology, 3rd. ed., Vol. 9, pp. 393-431, Wiley, New York, 1980.

87. Pace Petrochemical Service Annual Issue 1987, Pace Consultants, Houston, 1987.

88. Fox M., Acrylic Acid and Esters, SRI International, 1990.

89. Buchholz F. L., Keeping dry with superabsorbent polymers, CHEMTECH, September 1994, pp. 38-43.

90. Who is who in acrylics, Chemical Week, December 8, 1993, p. 12.

91. Acrylics: Versatile chemistry, Chemical Week, December 22, 1993, p. 22.

92. Fundamentals point to strong PTA growth as players jockey for position, Chemical Week, June 29, 1994, p. 18.

93. Purified terephthalic acid, Chemical Week, May 4, 1994, p. 23.

94. Key monomer growth rates, Chemical Week, March 30, 1994, p. 11.

95. Sulfonation and sulfation, in Kirk-Othmer's Encyclopedia of Chemical Technology, 3rd ed., Vol. 22, pp. 1-45, Wiley, New York, 1983.

96. Studying enzyme activity in supercritical fluids, CHEMTECH, March 1994, p. 33-37.

97. Wachs R., Yuval A., Zisner E., Membrane processes in industrial applications Israel Inst. of Chemical Engineers Journal, March 1994, p. 68.

98. Membranes recover chlorinated hydrocarbons, Chemical Eng., January 1994, pp. 17-18.

99. Pervaporation halves the cost of dewatering azeotropic mixtures, Chemical Eng., October 1993, p. 23.

100. Membrane recover VOC from gas streams, Chemical Eng., January 1994, p.17.

101. Titanium dioxide, Chemical Week, April 20, 1994, p. 48.

102. Purified terephthalic acid, Chemical Week, May 4, 1994, p. 23.

103. Acrylonitrile, Chemical Week, May 18, 1994, p. 64.

104. Acetic acid, Chemical Week, August 31, 1994, p. 48.

105. Methanol, ChemicalWeek, October 5, 1994, p. 48.

106. Butanes, in Kirk-Othmer's Encyclopedia of Chemical Technology, 3rd Ed., Vol. 12, pp. 910-919.

107. Global synthetic rubber capacity grew little in past decade, C&E News, May 10, 1993, p. 28.

108. Dow butadiene-to-styrene route could help cracker economics, Chemical Week, May 4, 1994, p. 11.

109. Plastics additives, Chemical Week, August 31, 1994, p. 23.

110. Ainsworth, S., Plastics additives, C&E News, August 31, 1992, p. 47.

111. Flame retardants project for Israel, Chemical Week, December 15, 1993, p. 48.

112. Magnesium hydroxide finds new applications, C&E News, October 25, 1993, p. 15.

113. The Dead Sea comes alive with new flame retardants, Chemical Eng., October 1993, p. 25.

114. Flame retardants, Chemical Week, April 15, 1992, p. 26.

115. Hindersinn R.H. Perspectives on polymer fire retardants, CHEMTECH, November 1990, pp. 672-676.

116. Specialties producers cope with mature markets, Chemical Week, July 27, 1994, p. 28.

117. Thayer, A., Use of specialty food additives to continue to grow, C&E News, June 3, 1991, p. 9.

118. Thayer, A., Food additives, C&E News, June 15, 1992, p. 33.

119. Emerging Technologies, U.S. Department of Commerce, Springfield. 1990, p. 30.

120. Cohendet, P., Ledoux, M., Zuscovitch, E., New advanced materials, Springer, 1988.

121. Frontiers in Chemical Engineering, National Academy Press, Washington, 1988, p. 64.

122. DeSapio, V., Advanced structural ceramics: Challenges to commercialization, CHEMTECH, November 1993, pp. 46-53.

123. Dendrimers branch out into the marketplace, Chemical Eng., November 1993, p. 51.

124. Lukehart C., Carpenter, J., Milne, S., Burnam, K., Creating better nanocomposites, CHEMTECH, August 1993. p. 29.

125. Supercritical water oxidation edges out incineration, Chemical Eng,. July 1993, p. 17.

126. Stinson, S.C., Chiral drugs, C&E News, September 19, 1995, pp. 38-72.

127. Makov, A., Seminar on the future of the chemical industry, Technion, November 2, 1994.

128. Kline et. al., Kline Marketing Guide to the Chemical Industry, Fairfield (1973).

129. Chemical Week, Jan. 1 1992, p. 18.

130. Wachs, R., in Technological Infrastructure Policy, Justman, Teubal, and Zuscovitch, eds., The Jerusalem Institute (1993).

131. Chemical Engineering, April 1992, p. 43.

132. Britannica World Data 1993, p. 822.

133. Economic Commission for Europe The Chemical Industry in 1992, p. 148, United Nations (1993).

134. Backman, J., The Economics of the Chemical Industry, Manufacturing Chemists Association (1970).

135. Bower, J., When Markets Quake, Harvard University Press (1986).

136. Reuben, B. G., Burstall, M. L., The Chemical Economy, Longman (1973).

137. Garrett, D. E., Chemical Engineering Economics, Van Nostrand (1989).

138. Facts & Figures for the Chemical Industry, C&EN June 1972 - 1993.

139. Berenson, C., The Chemical Industry (1963).

140. Achilladelis, B., Schwarzkopf A., , and Cines M., The dynamics of technological innovation, Research Policy, 19, 1 (1990).

141. Chemical Week, May 6 1992, p. 28.

142. Farm Chemicals, Chemical Week, Sept. 8 1993, p. 21.

143. Moore, S., Japan's CPI, Chemical Engineering, March 1993, p.32.

144. Dertouzos M.L., Lester R.K., and Solow R.M., Made in America, The MIT Press (1989).

145. Wei, J., Russell, T. W. F., and Swartzlander, M.W., The Structure of the Chemical Processing Industries, McGraw-Hill (1979).

146. Luberoff, B. J., Downsizing hasn't worked all that well, ChemTech, April 1993, p. 5.

147. Reengineering, Chemical Week, Nov. 24 1993, p. 28.

148. Hammer, M., and Champy, J., Reengineering the Corporation (1992).

149. Quest for profitability, Chemical Week, Oct. 13 1993, p. 20.

150. Dow Chemical: leading quiet revolution, Chemical Week, Sept. 29 1993, p. 33.

151. Dow at a glance, Company Profile (1992).

152. Great Lakes defies the odds, Chemical Week, May 6 1992, p. 26.

153. Chemical Week, May 12 1993, p. 59.

154. C&EN, Aug. 17 1992, p. 14.

155. Unified Europe, C&EN, Sept. 13 1993, p. 16.

156. Ainsworth, S., Specialty Chemicals loosing some luster, C&EN, Feb 11 1991.

157. United Nations Conference on Trade & Development, New York (1991).

158. German Chemicals, Chemical Week, Dec. 16 1992.

159. Schoenmakens., J., Reoganizing in the Netherlands, Chemical Week, July 28 1993, p. 24.

160. Country focus, Chemical Week, Sept. 22 1993, p. 10.

161. Hunter, D., Privatization, Chemical Week, Aug. 4 1993, p. 9.

162. Clear path into China, Chemical Week, Aug. 25 1993.

163. Greenwald, J., Japan: How the miracle ended, Time, Dec. 13 1993, p. 48.

164. Dun's Guide 10000, (1993).

165. Israel Chemical Catalog (1993).

166. Golden Screens.

167. The Industry in Israel 1992 in (in Hebrew), Ministry of Industry & Commerce, Jerusalem (1993).

168. Statistical Abstract of Israel (1993).

169. Chemical Week, Sep. 15 1993, p. 10.

170. Private communication.

171. Horowitz, U., The Techno-economic Analysis of Petrochemicals, Tahal Report (1993)

172. The Chemical Industry in Israel (in Hebrew), Ministry of Industry and Commerce (1978).

173. A year in the U.K. Chemical Industry, Chemical Week, Sept 22 1993, p. s10.

THE CHEMICAL INDUSTRY 2000

The International Chemical Industry and the Israeli Chemical Industry Potential for Future Growth

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The study presents data for the past two decades and analyses long term trends.

The performance of several large international companies is described, and the apparent unique characteristics of their strategy are presented.

The variety of strategies used by the Western chemical industry in order to improve the return to investors, did not result in significant improvements of the profitability or the growth rate for most companies.

The chemical industry in the Pacific Rim countries has undergone faster expansion than the Western chemical industry.

The performance of the Israeli chemical industry has taken an intermediate path between the slowed-down Western rate of growth and the impressive growth rate in the Pacific Rim, specially after 1989. However, the increment of the added value in the total value of the chemical shipments is low in Israel relative to other countries, due to a rather low level of integration. Another element of both strength and weakness of the Israeli chemical industry is the dominance of the agricultural market in the exports of the industry.

Comparison of the relative size of the chemical industry and its added value with those of the developed countries showed that there exists a potential for growth.

The study identifies market segments that are growing faster than other segments of the chemical industry, and suggests a general strategy for the Israeli chemical industry.

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